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p. 34

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July 2007

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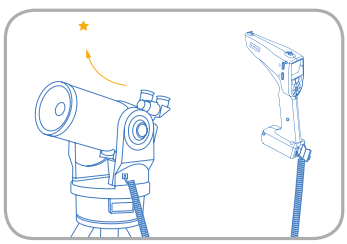

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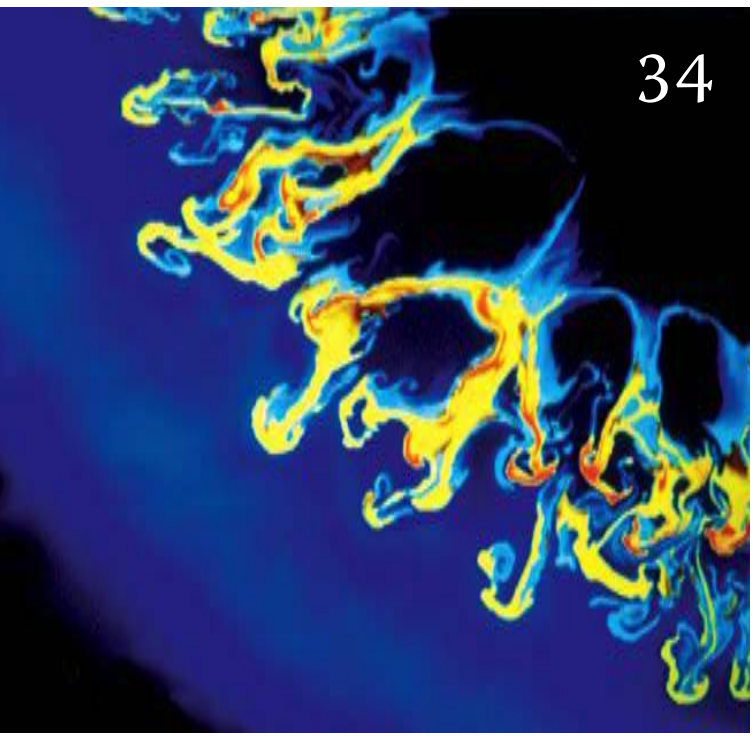

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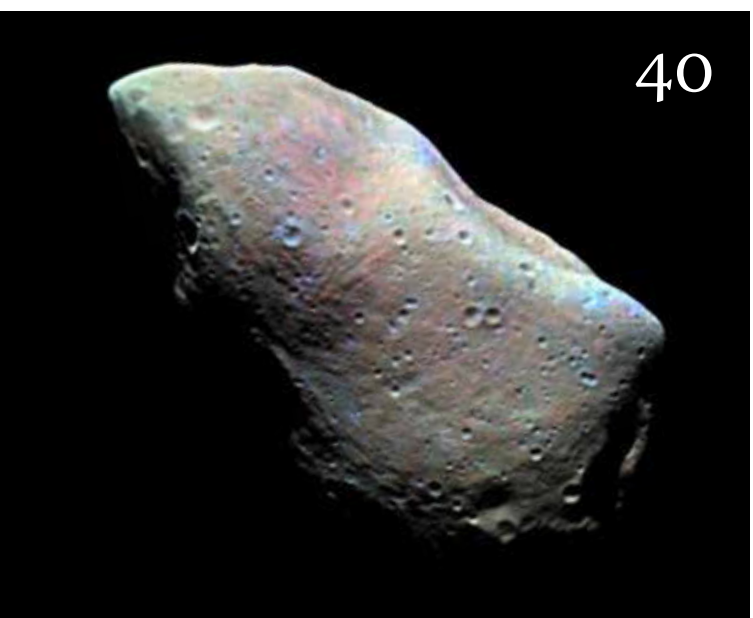

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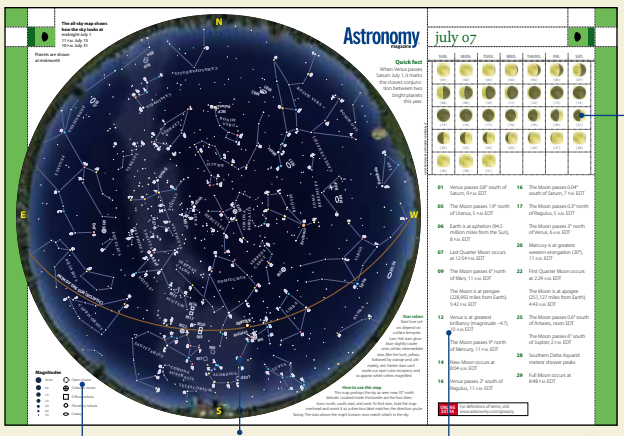

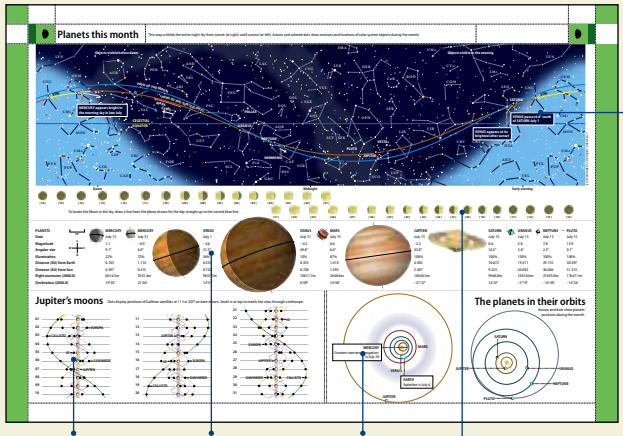

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LUND UNIVERSITY

TONY AND DAPHNE HALLAS

BY DAVID J. EICHER

The solar system's dark secret

In many science-fiction tales, the future

plays out pretty well, to a generally happy ending. But the solar system's real future will be grim. I don't mean the short-term future; I think, despite our many struggles, our civilization will be okay. I'm talking about the really long-term future — a billion to 5 billion years down the road. By then, the solar system will be radically changed, and the Sun will have scorched Earth.

"The first things to go will be Earth's glaciers and polar ice caps," writes Senior Editor Richard Talcott in this month's cover story, "Earth's deadly future," starting on page 28. "Warming surface temperatures will turn ice to water, leading to a slow but steady rise in sea level." What's to come will make our present global warming pale in comparison. "But it doesn't stop there," he continues. "Eventually, temperatures will rise high enough for seawater to boil away, leaving Earth bereft of this vital substance." By this point, life will have met its endgame on Earth.

Science fiction tackles the inevitable death and vacating of Earth with ease, suggesting humankind can simply jump ship and move to another, less hostile world. But in reality, even with the progress of technology over vastly long intervals, there would be severe logistical problems with moving an entire civilization.

Assume that it were possible to move civilization, or at least part of it, along with all the food and water needed to sustain it. Where could that civilization go? Mars would be the first option. Already the closest thing to Earth in terms of livability, Mars, at that point, would have heated up from its present cold state due to an increase in the Sun's luminosity.

"Unlike H. G. Wells' classic novel," explains Talcott, "in which dying Martians looked longingly toward a more hospitable Earth, earthlings may decide to head for cooler martian climes. Mars has a distinct advantage: Not only will it likely serve as humans' first permanent outpost in the solar system, it also holds the promise of being clement for an extended period."

But a possible stay on Mars would end when the Sun becomes a red giant. Its atmosphere would push out and heat the solar system such that "Miami Beach will exist on Pluto," as the old saying goes. By then, options for moving humans to another place in the solar system will run out, and humanity will perish.

Humans have been around for a couple million years. It's ridiculous to speculate about what might happen a billion years from now. But can humans even survive that long? Can we overcome the challenges posed by war, our degradation of the planet, or natural hazards like nearby supernovae or asteroid collisions? If we can, then we will one day face our greatest challenge ever, one that will not have the storybook ending we are used to getting from the movies.

David J. Eicher
Editor

Astronomy

Volume 35, Number 7

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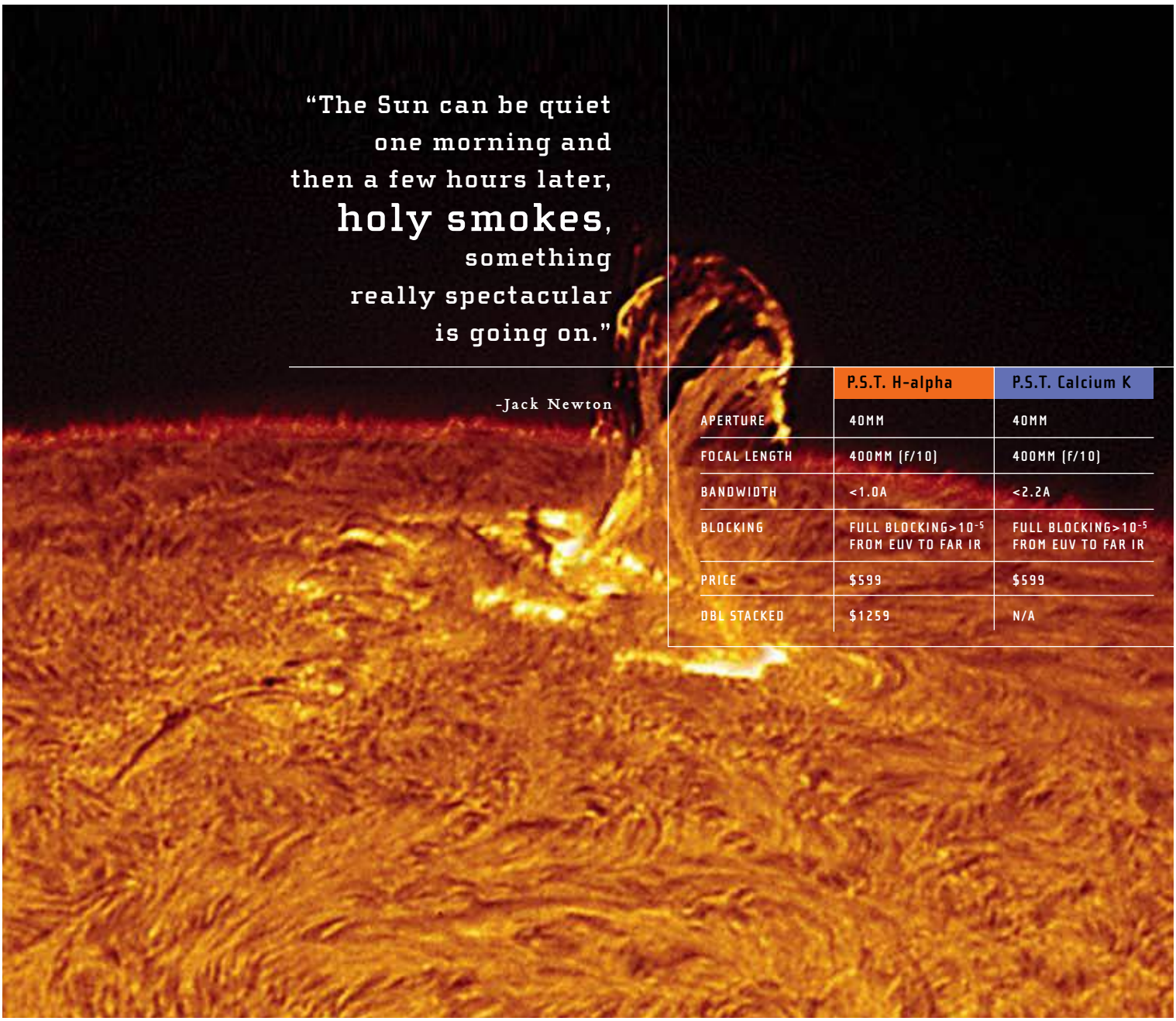

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Web savvy

THE LUNAR ECLIPSE of March 3 was a treat for those with a clear view. MARC PINTER-KRAINER

For the March 3, 2007,

lunar eclipse, the University of Toledo Ritter Planetarium and the Toledo Astronomical Association planned a joint viewing session at the planetarium's Brooks Observatory. Unfortunately, the clouds and a little snow blew in during the late afternoon. When the viewing was scheduled to start, it looked hopeless, but modern technology came to the rescue.

Our webmaster was positive some observatory would transmit eclipse views in real-time on the Internet. With a little work, we found an observatory in Belgium that was transmitting a picture of the eclipse every minute in full color.

We projected this on the screen in a classroom. Ironically, shortly after the eclipse ended, the clouds above Toledo departed, leaving a beautiful Full Moon. **— FRANK MERRITT,** TOLEDO, OHIO

All joking aside

I appreciated Bob Berman's April Fools' coded message ("If you were in charge," April 2007), but I would put my support behind all the "small" projects that need a champion, like:

• Funding to eliminate light pollution so people don't have to wait for blackouts, earthquakes, or trips to remote locations to see a dark night sky

• Putting a telescope in every school so kids can observe the Sun, our closest star

• Sponsoring huge star parties in every state that would motivate people to dust off their telescopes and binoculars — or just pull them away from the TV long enough to say "Wow!"

So, my vote for NASA's next "big" program is to think small. **— TRISTAM HARRINGTON,** OKEMOS, MICHIGAN

Poetry in motion

In Stephen James O'Meara's image of Scorpius' Graffias ("Poetry in motion," April 2007), there are four, not three, planets. The mountains in the lower part of the picture belong to Earth! **— JAVIER GONZÁLEZ,** SAN JUAN DEL RÍO, MEXICO

In "Poetry in motion," O'Meara tacitly suggests objects to the right of the midline are seen by the right eye, and those to the left by the left eye.

In fact, both eyes see the same field, except for the minor obstruction of the nose. All those objects to the right of center are recorded by the left retina of each eye and relayed to the left occipital cortex for visual perception.

All objects to the left of center do the opposite and are visualized in the right occipital cortex. So, putting an object to the left or right of midline changes the hemisphere of the brain that "sees" it.

Most right-handed people (left-brained) tend to be right-eyed, and many left-handed (right-brained) people tend to be left-eye dominant. **— DAN GOOD,** MILLERSVILLE, PENNSYLVANIA

Another perfect pair

I enjoyed James Mullaney's "Observe the sky's most colorful double stars" (April 2007). I'd like to suggest your readers look at OΣΣ 254 in Cassiopeia. It's fainter than those featured in the piece, but its deep red and blue components are worth the effort. **— BILL BADER,** EDEN PRAIRIE, MINNESOTA

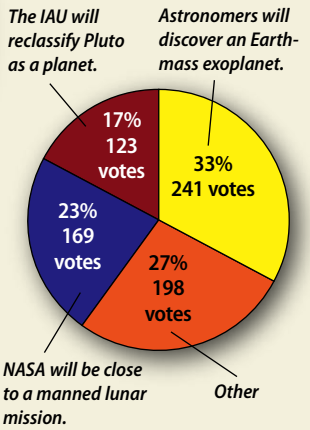
Correction

In March's Strange Universe, I said the Sun moves in a straight line across the sky only on the vernal equinox. I should merely have said "equinox." It happens, of course, on both equinoxes.
— BOB BERMAN

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Online poll results

POLL QUESTION:
Which is most likely before New Horizons reaches Pluto, in 2015?


The IAU will reclassify Pluto as a planet.
Astronomers will discover an Earth-mass exoplanet.
17% 123 votes
33% 241 votes
23% 169 votes
27% 198 votes
NASA will be close to a manned lunar mission.
Other

Total votes: 731

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Lifting the Swan's Veil

Imagine an exploding star so dazzling, it casts shadows and rivals a crescent Moon's brightness. That's what our ancestors saw after the glaciers receded from the last Ice Age, some 5,000 to 10,000 years ago. The supernova appeared in the constellation Cygnus the Swan at a distance of roughly 1,500 light-years. The blast ejected several solar-masses of hydrogen and heavier elements, which now glow softly as the Veil Nebula. The Veil spans nearly 3° — six times the Moon's apparent diameter. This ground-based image captures only a small part of the nebulosity, cataloged as NGC 6960, which surrounds an unrelated star, 4th-magnitude 52 Cygni.

T. A. RECTOR (UNIVERSITY OF ALASKA, ANCHORAGE)/WIYN/NOAO/AURA/NSF

BY BOB BERMAN

When do most people watch the sky?

In America, the answer is the Fourth

of July. In Canada, it's July 1. Waiting for fireworks to start, crowds of sky-impaired adults stare blankly into the darkening dome, unable to identify the stars and planets that make astronomy such a joy. This year around 9:30 P.M., Venus will capture millions of eyes, as it blazes in the fading twilight at its greatest brilliancy, a dazzling magnitude –4.6, in the western sky. Saturn conspicuously floats alongside, despite being 100 times less bright.

Meanwhile, Jupiter hovers in the southeast above Scorpius' bright star Antares. Many may see unfamiliar faces, but those who know the sky will find friends, not strangers, in the overhead arena.

You might also see flashes in the sky. Reflections from other towns' fireworks? Maybe. Except, mysterious flickerings erupt when there are no fireworks. Amorphous flashes in a clear, starry sky are surprisingly common. Seeing them doesn't mean some delusional alien life-form has taken you over.

Their usual cause is distant lightning. Unlike winter clouds, which cover extensive areas, the warm months often find clear skies in one community while thunderstorms erupt nearby. The high frequency of silent flashes in warmer weather may explain why they are commonly called heat lightning. There's really no such animal. When a nearly transparent layer of high, thin cirrus clouds is present, remote lightning can brightly reflect over the horizon from 50 miles (80 kilometers) away.

When lightning isn't responsible, the flash may have a true celestial origin — a dazzling meteor. Termed fireballs, or bolides when they explode, meteors brilliant enough to cast shadows burst overhead everywhere, several times each year. Some light up the countryside with enough brilliance to surrealistically influence the dreams of countless sleepers.

It doesn't take much mass to do the job. A 1-ounce meteor traveling 70,000 mph (114,000 km/h) will match Arcturus' zero-magnitude glow. A stony-iron specimen that's between pinball and fist size will flame as a fireball with colors rich enough to rival bursting skyrockets.

FLASHES MUST HAPPEN with a particular rhythm in order to be noticed.

A slow-moving flashing dot is usually a nonfunctioning satellite. Some 300 of these blink brightly as one side reflects the Sun as the satellites tumble. Iridium satellites, with their enormous solar panels, typically create a single, very brilliant flash.

Flashes must happen with a particular rhythm in order to be noticed. If they're too rapid, we simply won't perceive them. Human eyes typically can perceive flickers at a rate of about 20 flashes per second. Old silent movies, shown at 16 frames per second with a moment of darkness between each image, displayed obvious flickering to nearly everyone. When movies made the jump to 24 frames per second, the problem went away: Few people perceive any blinking when watching a modern film.

The sky's most famous flasher is the pulsar in the heart of the Crab Nebula, which blinks 33 times a second, well above the flicker threshold. Through a large amateur scope, its light seems steady. But you can force it to reveal its flashing nature by rapidly waving fingers back and forth in front of the eyepiece. Try out this technique while looking at a whirling fan. Keeping one eye open and your waving fingers nearby, you should be able, by varying your hand speed, to freeze the motion of individual blades.

The Crab's intense magnetic field acts as a brake and slows the wildly spinning star so that it will flicker just 17 times per second by the year 4000. Then, you'll see its flashes without all that hand waving, which has already convinced passersby you're nuts.

Unfortunately, the universe's most exciting flashes — supernovae — have been confined to external galaxies for the past 4 centuries. The closest in our lifetimes lay 165,000 light-years away in the Large Magellanic Cloud, appearing as a magnitude 3 star to my group who traveled to Central America to see it in 1987. None has occurred in our Milky Way since 1604. One supernova per century per galaxy is considered normal, so we're long overdue.

When a supernova flashes in our galaxy, I hope it chooses an occasion when everybody's already gazing skyward. Farfetched? Maybe not. The most famous supernova of all, which was dazzling enough to cast shadows and powerful enough to create the Crab Nebula, set off its fireworks exactly 953 years ago — on the Fourth of July.

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BY GLENN CHAPLE

Having an Earth-moving experience

It began with an e-mail from Bill

Cromwell of Ft. Louden, Pennsylvania, who felt that he could "get in the zone" and sense the apparent westerly drift of the stars with Earth's rotation. I mentioned Bill's observation in a column I wrote about Earth-sky motions in the February issue. The article elicited many responses from readers.

The first came from *Astronomy Brasil* editor and publisher Ulisses Capozzoli. "I was on top of a mountain (Serra da Mantiqueira, southwest region of Brazil) and could feel the sky's motion for a fraction of time. It is a fantastic experience, but for many people it could be a little exotic." Fellow Brazilian Vandenberg Lima observes sky motion using "the constellation of the Cruzeiro [Southern Cross] together with Alpha and Beta of the Centaur."

Doug Kniffen of Warrenton, Missouri, suggests "moving your eyes the opposite of 'cross-eyed.' Once you've done it a few times it won't be uncomfortable. Looking toward the celestial equator and the meridian is the easiest place to test your new-found skill. You'll be shocked at how obvious the apparent motion is."

Two readers got "zoned" while sitting on a ledge. Paul Barby of Tucson, Arizona, recalls "a clear night in Beaver, Oklahoma, in the late 1970s. As I gazed for a couple of minutes, I suddenly became aware of the motion of the stars across the sky — actually a sense of moving with Earth. It was quite powerful, giving me a fleeting sense of vertigo that caused me to brace my hands on the ledge."

Don Byrd of Pawtucket, Rhode Island, describes a "ride" in the Shenandoah Mountains of Virginia "early in the morning, while sitting on a cliff with my legs hanging over the edge. Some moments before sunrise, I slowly began to feel that I was coming up to the top of a giant Ferris wheel. As the Sun appeared on the horizon, I got a distinct feeling that I was moving and the Sun wasn't. It was breathtaking!"

JUPITER WAS EASY to follow from this location by tracing the planet as it passed through tree branches. JOE ORMAN

Can't get "zoned?" Try a reference point. Paul E. Mitchell of Glen Spey, New York, observed "the motion of the stars became very apparent in relation to the roof." Ken Fiscus of Albert Lea, Minnesota, "noticed brilliant Venus shining through a lace curtain. ... As I held my breath to stay steady, I watched Venus appear and disappear through the lace curtain's threads and gaps."

An occasional glance reveals diurnal sky motion. R. C. Timm of Florissant, Colorado, "can judge the time spent in [his] hot tub by watching the stars pass behind or between the trees. Periodic checking reveals their movement." Jim Foley of Calabasas, California, remembers observing with his daughter, Megan. "Our balcony had a great view of the southern sky. I marked a spot on the door jamb, and had her rest her head against it. I pointed out a bright star, showing her that it was fairly close to a big branch of a tree. We kept returning to that same spot, and she rested her head against the same mark. Megan was amazed to see that star move into the trees, past a branch, and out the other side."

Michelle Chattaway of Langley, British Columbia, recalls "watching Venus and a thin crescent Moon move across my Venetian blinds. I had to lie really still to see it."

The Sun reveals diurnal motion, as observed by Matthew Buckingham of Heath, Ohio. "I was sitting in my car enjoying a break from work. Every time I looked out the window, I noticed the Sun's reflection off the mirror of the neighboring car was always different! I watched the reflection actually move back and down the side of the car!"

Roy Matchko of Payson, Arizona, offers a high-tech way of documenting sky motion: Watch the sky move through a linear polarizer or a polarization axis finder. "Skylight is polarized, and the polarization azimuth angle of skylight at a given viewing point changes as Earth rotates and the apparent position of the Sun changes."

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

Next month: Measuring sky angles.

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BY PHIL HARRINGTON

Here's just what the doctor ordered

"What's your sign?" Many people have uttered that line as an ice breaker in social settings since the 1960s. One person wants to know another person's astrological birth sign. We've all learned that there are 12 signs of the zodiac along the Sun's annual path around our sky. Did you know that the Sun actually passes through 13 constellations? Those born between November 30 and December 17 are not Sagittarians. They're Ophiuchians!

The Sun passes through Ophiuchus the Serpent-Bearer's southernmost extremes late every year. Ophiuchus represents Asclepius, a legendary doctor and healer in Greek mythology.

All that's half a year away. Tonight, we find Ophiuchus looming large in our evening sky. Looking its way, our gaze skirts the northern edge of the Milky Way's core. That's why Ophiuchus swarms with globular clusters — more than any other constellation. The brightest are visible through 7x35 binoculars, if you know exactly where to look. Read my online extra on Astronomy.com this month, and we'll try to find a few.

For now, let's concentrate on Ophiuchus' northern region. Rasalhague (Alpha [α] Ophiuchi) represents the physician's head. Two fainter stars — Kappa (κ) Ophiuchi to the west and Cebalrai (Beta [β] Ophiuchi) to the southeast — mark his shoulders.

Take aim at Cebalrai and look just to its north for a group of faint points. That's open cluster **IC 4665**. Even through the smallest pocket binoculars, IC 4665 resolves into a beautiful collection of about three dozen blue-white suns. I always find it interesting that Charles Messier missed this grand object when compiling his list. If only he had used binoculars!

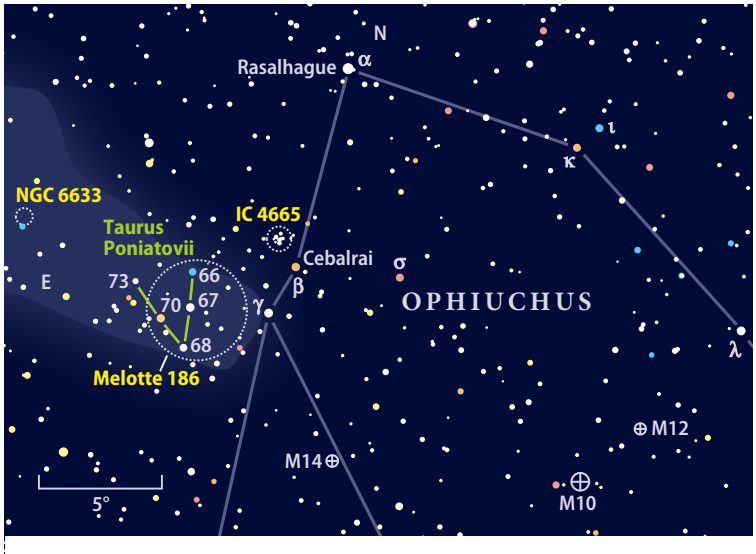
Shift about half a binocular field of view east of Cebalrai, and you'll come to 5 stars in a V pattern that looks like a miniature Taurus the Bull. In fact, 220 years ago Polish astronomer Martin Poczobut proposed that these same stars be christened **Taurus Poniatovii**, or Poniatowski's Bull, after Polish King Stanislas Poniatowski II. But after the king's reign ended, Poniatowski's Bull quickly lost favor among astronomers, and is no longer an officially recognized constellation.

Taurus Poniatovii is a fun catch through low-power, wide-field binoculars. The brightest star in the V pattern, 70 Ophiuchi, shines with a warm orangish tint. Although 70 is just 16 light-years away, some of the other, more distant members of Taurus Poniatovii, as well as other surrounding stars, belong to the scattered open cluster **Melotte 186**. Unfortunately, it's tough to tell at a glance exactly where the cluster begins and ends.

Finally, scan a binocular field to the bull's northeast to see a third open cluster. **NGC 6633** is quite large as clusters go, covering about a Full Moon's diameter in our sky. Binoculars display more than two dozen 8th-magnitude stars glimmering like blue-white gems against the dim glow of the few cluster members left unresolved.

Have any suggestions for fun and challenging binocular targets? E-mail me at phil@philharrington.net.

Next month, we'll get together for a spot of celestial tea. Remember, two eyes are better than one.



OPHIUCHUS the Serpent-Bearer's lower half possesses objects that attract the majority of stargazers, but the upper half hosts a number of gorgeous and challenging binocular targets. *ASTRONOMY:* ROEN KELLY

ONLINE EXTRA Take a deeper look at 3 Messier objects found in Ophiuchus at www.astronomy.com/toc.

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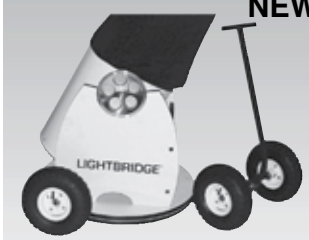

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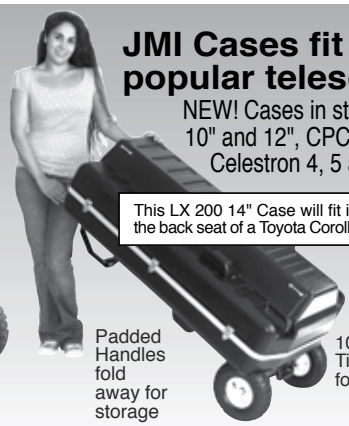

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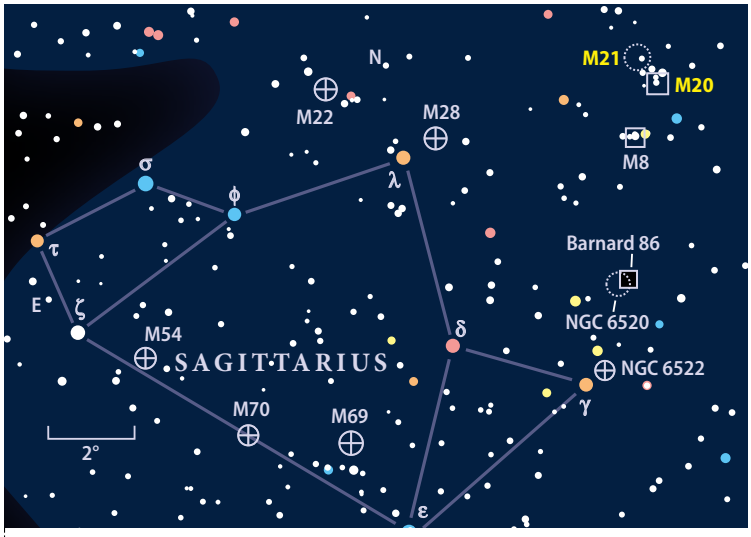
BY STEPHEN JAMES O'MEARA

The curious history of M20 and M21

Anyone familiar with the original list

of nebulae and clusters compiled by 18th-century French comet-hunter Charles Messier has come to associate his 20th catalog entry with the Trifid Nebula (M20). The Trifid is a summer favorite among amateur astronomers, who enjoy enjoy seeking out the three main rifts of obscuring dust, which spread from the Trifid's core like roots from a tree.

The Trifid is a wonder. With an estimated age of only 300,000 years, it is one of the youngest star-forming regions known. The nebula glows primarily pink, as radiation streaming from a hot, magnitude 7.6 star near the Trifid's heart fluoresces the surrounding gases. Actually, this star is the brightest member of the famous triple-star system HN 40, which itself is part of a young star cluster. The cluster's northern border is defined by a 7.4-magnitude sun less than 10′ to the north-northwest, which is surrounded by a vast, although somewhat dim, blue reflection nebula. The entire nebula complex lies some 5,000 to 9,000 light-years distant and, seen together, is a stunning and colorful sight in photographs.



POSITIONED ABOVE THE TEAPOT, M20 and M21 are easily located by following the "steam" rising from the asterism's spout. *ASTRONOMY:* ROEN KELLY

Of course, Messier knew none of this. In fact, the 20th object in his catalog has a certain air of mystique — a mystery into which you might like to immerse yourself. Let's start with Messier's original description of M20. Here is how it appears in his first catalog, published in the *Connaissance des Temps* for 1774: "Star cluster, slightly above the ecliptic, between the bow of Sagittarius and the right foot of Ophiuchus."

Notice anything peculiar? Messier doesn't mention the nebula. This is not surprising, given that Messier could hardly see any nebulosity in M8, which is not only brighter than the Trifid Nebula but has a higher surface brightness. Messier was an excellent observer, but he was limited by his telescopes' poor optics and the latitude at which he lived (about 50° north). From his native Paris, M8 and M20 achieve an altitude of only roughly 15° when highest. So, Messier had to look at them through dense and smoggy skies. The 19th-century British observer Admiral William Henry Smyth voiced the difficulty of observing the Trifid Nebula from high northern latitudes, writing, "though I could make out the delicate triple star in the centre of its opening, the nebulous matter resisted the light of my telescope so that its presence was only indicated by a peculiar glow."

At a glance, then, it appears that M20 is not the Trifid Nebula, but its associated cluster. There's more. The same night Messier observed M20, he also determined the position for the star cluster M21, which is about 40′ to the northeast. In his catalog, Messier simply described M21 as a "[s]tar cluster close to the previous one [M20]." But in his descriptive notes, Messier combines his observations of M20 and M21, noting that "the stars in these two clusters are of eighth and ninth magnitude, and are surrounded by nebulosity."

The mystery here is that while the cluster M20 is indeed enveloped in nebulosity, M21 is not. Smyth conjectured that Messier "seems to have included some bright outliers in his description, and what he mentions as nebulosity, must have been the grouping of the minute stars in view." One could also argue that Messier is referring to the naked-eye view. M20 and M21 are both involved with a roughly cruciform group of these 6th- to 7th-magnitude suns that looks nebulous to the unaided eye.

M20 (RIGHT OF CENTER) and neighboring open cluster M21 (left of center) are companions in a cosmic whodunit. The essence of this mystery centers around which observer should be credited with their discoveries. LAWRENCE JOHNSON AND KATHY ORTEGA/ADAM BLOCK/NOAO/AURA/NSF

But there is yet another curiosity. In his notes on M20 and M21, Messier says that the "known star closest to these two clusters is seventh-magnitude Flamsteed 11 Sagittarii." As Robert Burnham, Jr., notes in his *Celestial Handbook* (1978), this is puzzling because 11 Sagittarii is about 2° to the southeast of the clusters, whereas 5th-magnitude 4 Sagittarii is much closer.

The question of who discovered M20 and M21 adds to the mystique. In the *Connaissance des Temps* for 1774, Messier is careful to note which objects he discovered. In most cases, he separates these discoveries from his task of determining the positions of known objects. In Messier's descriptive notes for M20 and M21, he does not say he discovered them. He writes only that on the same night he discovered M19, he "determined the position" of these two star clusters.

Several sources cite French astronomer Guillaume Le Gentil as the probable discoverer of M20. The problem is that, to my knowledge, Le Gentil discovered only one object in the region. Unfortunately, the published position of that object is in error. This fact led 19th-century French astronomer Guillaume Bigourdan to propose both M8 and M20 as possible identifications for Le Gentil's nebula — thus the confusion.

We do know that Messier drew on Le Gentil's published lists of nebulae for his own catalog. To create his catalog, Messier sought out known clusters and nebulae and determined accurate positions for them. He undoubtedly must have encountered Le Gentil's positional error. Since the 8th object in Messier's catalog had already been accurately cataloged by John Flamsteed (1646–1719) and others, it's possible Messier assumed Le Gentil's nebula was a new object — especially since Le Gentil notes that this object in Sagittarius is one of "several other [nebulae] which most probably have not been mentioned by Astronomers." After sweeping the heavens around Le Gentil's erroneous position, Messier must have encountered M20 and M21, which lie about 2° and 3° to the north-northeast, respectively. Not knowing which object Le Gentil discovered, it's possible Messier simply determined the positions of both objects and left it at that.

As for the Trifid itself, I believe Messier did see the glow from the nebula. But if he didn't, then the discovery clearly goes to 18th-century astronomer William Herschel, who cataloged it as four separate nebulae: H-IV 41, 10, 11 and H-V 12. William's son, John, was the first to refer to it as the Trifid in his *Outlines of Astronomy* (1849): "One of them [several nebulae in Sagittarius] is singularly trifid."

So, during your next observing session, give this region a look and e-mail your thoughts to me at someara@interpac.net.

TAKE TWO Observations show asteroid 90 Antiope is binary — a pair of 56-mile-wide (90 kilometers) boulders traveling together.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

NASA/ESA/M. DAVIS (UC, BERKELEY)/S. FABER (UC, SANTA CRUZ)/A. KOEKEMOER (STScI)

GALAXIES GALORE. **Hubble imaged at least 50,000 galaxies as part of a new survey that looks 8 billion years into the universe's past. Hubble needed 500 exposures to capture one-third of the survey's total area. The view here shows a small fraction of the whole Hubble mosaic.**

24 From the Moon to Earth

25 X-raying the Eagle

26 Black holes by the thousands

27 Titan's Black Sea

27 Viewing the universe 8 billion years ago

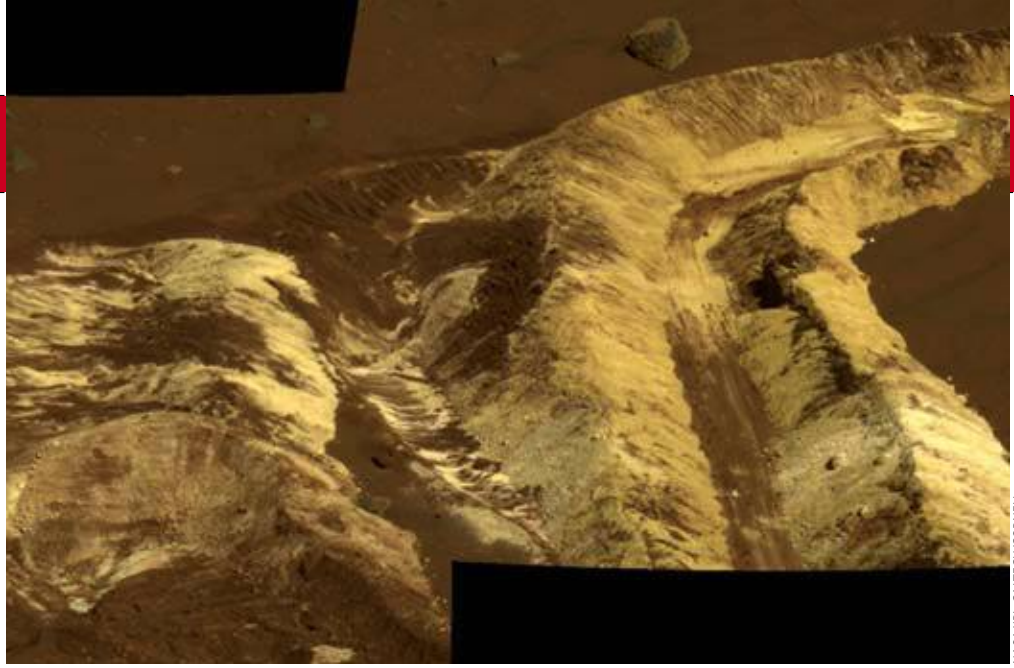
Eight telescopes on Earth and in space have gone deep to create an all-color map of a patch of sky. The 5-year project captured some 150,000 galaxies in an area the width of two Full Moons near the Big Dipper.

"The goal was to study the universe as it was when it was about half as old as it is at present," says team leader Marc Davis of the University of California, Berkeley.

The project, called the All-wavelength Extended Groth Strip International Survey (AEGIS), studied the region at radio, infrared, visible, ultraviolet, and X-ray wavelengths. By looking back 8 billion years, the scientists focus on a time when galaxies were settling down after their turbulent early years.

One surprising result: Although many galaxies back then looked different than they do today, some fundamental properties have changed little. A research team led by Susan Kassin of the University of California, Santa Cruz, found the relation between a galaxy's mass and the orbital speeds of its stars and gas remains the same for all types of galaxies over billions of years of cosmic evolution.

Other findings include the discoveries of several gravitational lenses and a giant galaxy with two supermassive black holes 4,000 light-years apart. The researchers published 19 papers on the survey in a special issue of *Astrophysical Journal Letters*. — **RICHARD TALCOTT**



NASA/JPL-CALTECH/CORNELL

SIX WHEELIN'. **The Spirit rover dug up this bright soil when one of its six wheels got stuck. This sulfur-rich soil contains a trace of water.**

Mars rovers trek up and down

After a long winter of inactivity, NASA's Spirit rover has stirred from its slumber. The spacecraft resumed its exploration of Mars' Columbia Hills in late 2006, after spending 7 months parked on an 11° slope facing the Sun. Mission controllers used this tactic during the long southern winter because Spirit's solar panels couldn't provide much power.

Halfway around Mars, Spirit's twin, Opportunity, continues to circumnavigate Victoria Crater. This half-mile-wide (800 meters) crater has been Opportunity's home since September 2006. Steve Squyres of Cornell University, principal investigator for the rovers, reported on the rovers' recent exploits March 14 at the 38th annual Lunar and Planetary Science Conference in Houston.

Although Spirit remained stationary, it didn't shut down. Among other tasks, Spirit analyzed some bright soil it picked up when the drive actuator on its right-front wheel failed. The analysis shows the intriguing yellow-white material is rich in sulfur and contains a trace of water.

Meanwhile, Squyres and his team are committed to driving Opportunity into Victoria, if they can be sure they'll get it out again. Squyres is confident they can, and he expects the trip to happen sooner rather than later. — **R. T.**

Rosetta comet probe sees red

The European Space Agency's Rosetta comet mission put on the brakes February 24/25, when it flew within 155 miles (250 kilometers) of the martian surface. The spacecraft lost 4,901 mph (7,887 km/h), slowing to 22,488 mph (36,191 km/h) relative to the Sun, sending it back toward the inner solar system, where it is on track to swing past Earth for another gravity assist in November.

In 2014, the spacecraft will reach Comet 67P/Churyumov-Gerasimenko. The craft has two parts: an orbiter that will remain with the comet as they approach the Sun, and a lander. Mission controllers used the February Mars flyby to test the orbiter's camera, named OSIRIS, and the lander's imaging system, called CIVA. — **R. T.**

ESA/MPS

RED PLANET. **Rosetta's camera took this image of Mars February 24 from a distance of 150,000 miles (240,000 km). The image shows details as small as 3 miles across (5 km).**

QUICK TAKES

WATER WORLD
Ice at Mars' south pole holds enough water to give the Red Planet a global ocean 36 feet (11 meters) deep.

MAKE THAT A DOUBLE
The Spitzer Space Telescope spied many debris disks around binary stars, making it likely planets can exist in such systems, too.

NEAR MISS?
On March 27, an airline pilot saw "flaming debris" falling 5 miles (8 km) in front of the plane. Initially thought to be Russian space junk, the object likely was a meteoroid.

SIMPLE NO MORE
Globular clusters like Omega Centauri and NGC 2808 show surprising variety in their stellar makeups, suggesting multiple star-forming episodes.

STICKY SOIL
Dust particles smaller than 2.5 micrometers can stick in human lung tissue. Lunar dust contains up to 3 percent of such particles by weight — a hazard for astronauts.

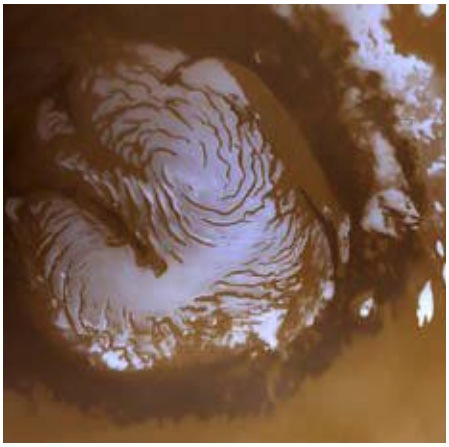
SALT BOWL
The Silverpit Structure, once considered the UK's only impact crater, may be a scar caused by salt movement.

INFLIGHT MEALS
Space tourist Charles Simonyi ate well on his trip to the International Space Station, bringing gourmet meals to share with ISS crewmates.

STOCKTON STRIKE
A 3.4-mile-wide (5.5 km) submarine feature west of Stockton, California, may have formed when an asteroid or comet struck Earth 40 million years ago.

DYNAMIC DUO
A small Chinese satellite will piggyback to Mars' big moon aboard Russia's Phobos Grunt spacecraft in October 2009.

MARS FLU
In a poll of 74 Australian astronomers, only half stated "complete confidence" that NASA would be able to contain any organisms brought back by a sample-return mission planned for 2020.



NASA/JPL/MSSS

AUTUMN SNOW. Global Surveyor snapped this image of Mars' northern hemisphere in early summer, when carbon-dioxide snow depths are at a minimum. In late autumn, the depth reaches a maximum of 80 inches (2 meters) at the edge of the permanent cap.

Let it snow!

Planetary scientists say the carbon-dioxide snow on Mars falls heavier in the northern hemisphere than in the southern. David Smith of NASA's Goddard Space Flight Center and Maria Zuber of MIT discovered this disparity after measuring snow depths in both hemispheres over the course of a full martian year. They reported their findings March 12 at the Lunar and Planetary Science Conference in Houston.

Smith and Zuber found snow depth increases fastest in late fall, when atmospheric temperatures plummet and carbon dioxide precipitates out of the air. In the north, snow depth increases steadily northward from about 50° latitude. It then takes a big jump at 80° latitude — the edge of the permanent polar cap — where it reaches a maximum depth of about 80 inches (2 meters). The polar cap itself shows less snow accumulation.

Snow in the southern hemisphere shows two major differences. First, snow depth increases steadily from 50° south latitude all the way to the pole. There were no sudden jumps and no pronounced changes at the permanent polar cap's edge. Second, the total volume of snow in the southern hemisphere is significantly less than in the northern. — **R. T.**

From the Moon to Earth

With China's first Moon probe expected to launch early this fall, and India's first Moon mission (carrying several U.S. science instruments) to follow next year, it's nice to think these new players in lunar orbiting are devoted to pure research and peaceful science. After all, the Moon is a long, long way from earthly squabbles.

But underappreciated lessons in recent space navigation should remind us the Moon has enormous value beyond its troves of knowledge and possible material wealth. It has a nearby gravity field, which commercial interests have already exploited and plan to do again. Ultimately, the potential to exploit the Moon's gravity for military purposes needs wider recognition, if only to dissuade those who might be tempted.

The technique's first success came in 1999, when a rocket malfunction stranded a commercial communications satellite in a useless transfer orbit. The satellite did not have enough fuel to reach the desired 24-hour orbit directly, and the insurance company paid off on the "total loss."

The company then boldly hired some innovative celestial mechanicians to plot a path to the Moon, where a close swing-by twisted the satellite's orbital plane into the desired orientation and sent it back toward Earth. There, a gentle rocket burn slowed the satellite into its proper operational orbit. And a commercial customer began paying for its services.

Russian space navigators had known about this potential trick for years. Their interest stems from Russian launch sites being located so far north. This means rockets need to carry lots of fuel to change a satellite's orbital plane to the highly desired equatorial final orbit. Launching one of their standard rockets from the equator would double its deliverable payload. (The Russians are now building exactly that kind of launchpad at Kourou, French Guiana.) Flying past the Moon provides similar performance benefits.

The military angle is a little frightening. China's anti-satellite rocket test in January was shocking, but not too worrisome because such a weapon can't reach high-altitude orbits. Rockets that might be launched toward critically important defense satellites in 24-hour orbits or in the 12-hour orbits used by navigation payloads would be detected easily as they flew.

ESO

MOON SHOT. The Moon provides a cheap — and potentially dangerous — method for getting satellites into Earth orbit.

But a probe rounding the Moon and headed back to Earth would be absolutely undetectable by radar or by telescope. It could slip into an orbit matching its target, and even its braking rocket burn would almost certainly pass unnoticed. The craft could lurk nearby for future activation — or simply create the fear that it and others like it were lurking nearby — and seriously erode confidence in the survivability of space infrastructure.

This stealth space threat, sadly, is made possible by the Moon's nearby gravity field and by human ingenuity. Another flavor of ingenuity may be able to counter such vulnerabilities one day. But either way, the Moon is much more involved in earthly affairs than most people would have dreamed, or hoped. — **JIM OBERG**

CLEMSON UNIVERSITY

GLOWING TRAILS. A chemical trail left by a NASA sounding rocket glows in the sky over Alaska's Poker Flat Research Range.

Rockets over Alaska

Clemson University researchers launched four rockets January 19 from the Poker Flat Research Range north of Fairbanks, Alaska, into the aurora borealis (northern lights) to learn more about heat in Earth's upper atmosphere.

The NASA suborbital sounding rockets carried chemical-tracer experiments into a bright auroral display over the northernmost state. The tracer glows when it reaches an altitude of 60 miles (100 kilometers), allowing the researchers to track the glowing trail as atmospheric winds buffet it.

Why shoot rockets into the aurora? "We are interested in the auroral displays because they produce electrical currents that heat the atmosphere," says Miguel Larsen of Clemson. "Wind patterns become altered as the atmosphere heats up, and this can cause changes in satellite orbits and interference with radio communications." — **LAURA LAYTON**

X-raying the Eagle

Astronomers using NASA's Chandra X-ray Observatory have peered into the Eagle Nebula (M16) in Serpens and found this hotbed of star formation is now past its prime.

The Chandra data show many bright X-ray sources in the field, but few in the "Pillars of Creation" imaged by Hubble in the 1990s. Because young stars typically emit lots of X rays, this suggests the Eagle is no longer the star-forming machine it was a few million years ago. One of the few youths appears as a bluish object near the tip of the left-hand pillar.

Jeffrey Linsky of the University of Colorado led the team that took these high-resolution X-ray images of the Eagle Nebula. The astronomers reported their results in the January 1 *Astrophysical Journal*. — **R. T.**

X-RAY: NASA/CXC/U. COLORADO/J.LINSKY ET AL.; OPTICAL: NASA/ESA/STSCI/ASU/J. HESTER AND P.SCOWEN

PILLARS OF CREATION. Chandra imaged dozens of X-ray sources in the Eagle Nebula, but few in the dusty pillars imaged by Hubble (also shown in this composite). This suggests the Eagle is in the last stages of star formation.

BRIEFCASE

Supplying a mission

MIT researchers Olivier de Weck and David Simchi-Levi have created *SpaceNet*, a software tool for modeling interplanetary supply chains. Version 1.3, released in March, simulates the flow of vehicles, crew, and supplies needed to support exploration missions. — **L. L.**

Heat is on

In March, the European Space Agency's Cluster spacecraft observed magnetic field lines reconnecting within turbulent plasma in Earth's magnetosphere. Scientists surmise similar events on the Sun may accelerate particles to high energies, heating the solar corona. — **L. L.**

AAS picks president

The American Astronomical Society elected John P. Huchra of the Harvard-Smithsonian Center for Astrophysics as its 42nd president. Huchra succeeds University of Texas astronomer J. Craig Wheeler, and will serve from June 2008 through June 2010. — **L. L.**

25 years ago in *Astronomy*

July 1982

In July 1982, our late-breaking story was "Revealing the Venusian Secrets," a look at preliminary results from the Soviet Union's Venera 13 and 14 missions. The two spacecraft transmitted data from Venus' surface for 127 minutes and 57 minutes, respectively, before they succumbed to the hostile conditions.

They survived long enough to give scientists a detailed look at soil composition, rock formations, and atmospheric conditions — as well as returning the first color images from our neighbor's surface.

At a time when budget constraints were curtailing U.S. planetary exploration, the Venera missions reminded us of what we were missing.

July 1997

10 years ago in *Astronomy*

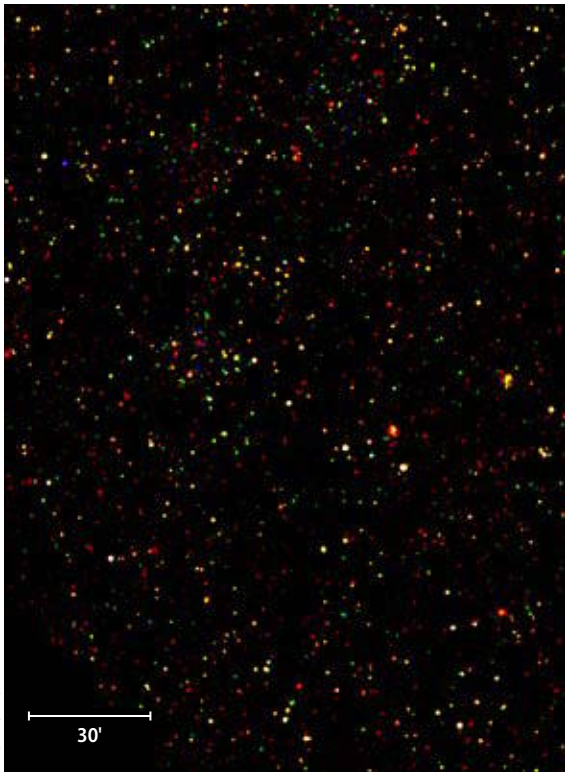
Astronomy introduced a new look in July 1997, including a full-bleed-photo cover design and a new department called "Ask Astro." The lead feature was "Inflating the Cosmos." This story detailed cosmic inflation — the idea that the universe underwent a period of exponential expansion within a fraction of a second after the Big Bang.

Inflation not only smoothed out space-time (solving the "flatness problem"), but also allowed parts of the cosmos in thermal equilibrium to expand to opposite sides of the universe (solving the "horizon problem").

Author Timothy Ferris wrote that despite its simplicity, "Inflation may well rank among the most productive ideas of modern cosmology." — **KATIE NEUBAUER**

NO-ZONE Greenland ice cores reveal a massive 1859 solar flare destroyed more stratospheric ozone than any similar event recorded since.

Black holes by the thousands



ASA/CXC/CFA/R. HICKOX ET AL.

Astronomers using NASA's Chandra X-ray Observatory and Spitzer Space Telescope, along with two ground-based scopes, have discovered more than 1,300 supermassive black holes in the distant universe. The findings raise questions about a popular model that describes how such black holes feed off their surroundings to create active galaxies.

The final image covers 9.3 square degrees — more than 40 times the area of the Full Moon — in the northern constellation Boötes. The black holes lie anywhere between 6 billion and 11 billion light-years from Earth, and each weighs from hundreds of millions to several billion times the mass of the Sun.

Most astronomers think a torus of gas surrounds an active galaxy's central black hole, feeding the activity. If true, toruses should obscure some of the nuclei. In a large sample of black holes like the Boötes one, astronomers would expect the absorption to range from none to complete, with most in-between.

"Instead of finding a whole range, we found nearly all of the black holes are either naked or covered by a dense veil of gas," reports team leader Ryan Hickox of the Harvard-Smithsonian Center for Astrophysics. "Very few are in-between, which makes us question how well we know the environment around these black holes." — **R. T.**

BLACK-HOLE ZOO. More than 1,000 actively feeding supermassive black holes (the bright dots) turned up in this Chandra X-ray image of Boötes.

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STAR CITY. **Astronomers have found a globular cluster in the inner Milky Way. It appears as a circular region of stars at this image's center.**

A new Milky Way globular

Bright and showy, globular clusters stand out from far away. Surely, astronomers have cataloged all of our home galaxy's globulars, right?

Not so fast. A team of European astronomers has discovered what appears to be a globular cluster lurking behind thousands of light-years of gas and dust. Led by Dirk Froebrich of the United Kingdom's University of Kent, the team observed in the near-infrared to penetrate this thick galactic "fog."

The globular, designated FSR 1735, lies some 30,000 light-years from Earth and 10,000 light-years from the galaxy's center. It contains approximately 100,000 stars. The team reports its results in the April *Monthly Notices of the Royal Astronomical Society*. — **R. T.**

NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

GLOWING EYE. **The reddish center of the Helix Nebula in this Spitzer infrared image points to a rash of comet collisions in the aftermath of a Sun-like star's death.**

Comets clash in the Helix

Cosmic dust usually shows up where stars are born, not where they expire. But that's not the case in the Helix Nebula (NGC 7293), the remains of a dying star in Aquarius. The Helix is a planetary nebula, a ring of gas formed when a Sun-like star ejects its outer layers.

Astronomers studied the Helix with the Spitzer Space Telescope. The infrared image reveals a dusty disk at the nebula's heart, looking like a red pupil set in a blue-green "eye" of glowing gas.

"We were surprised to see so much dust around this star," says team leader Kate Su of the University of Arizona. Any lingering dust in the system should have been blown away when the star expelled its envelope.

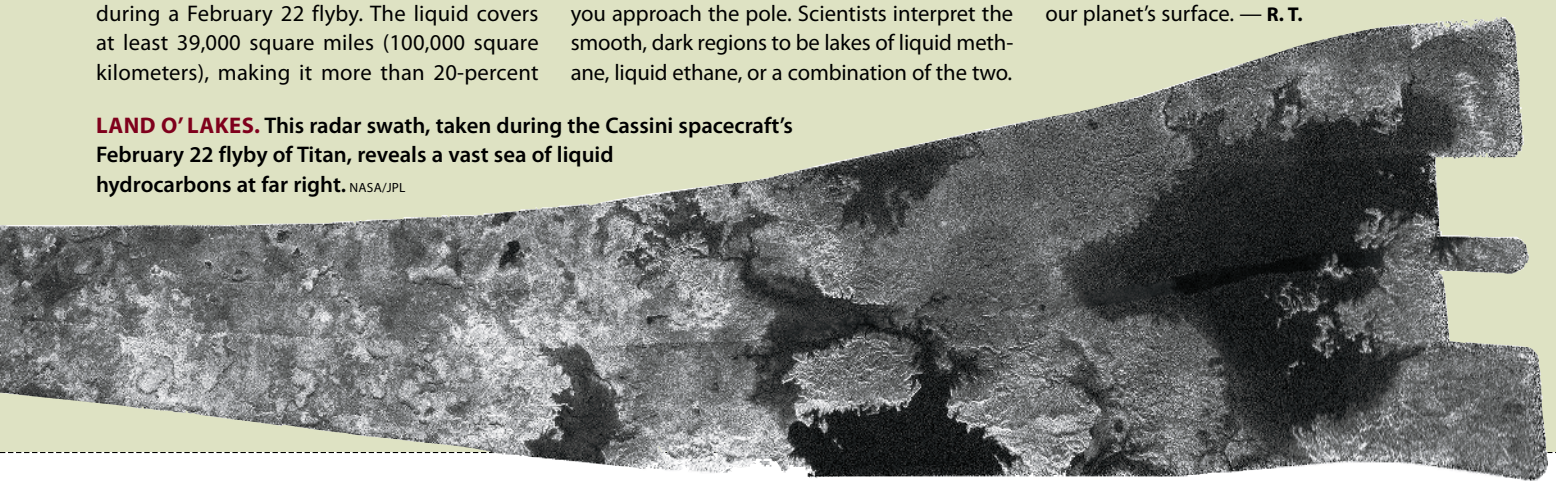
"The dust must be coming from comets that survived the death of their sun," explains Su. The star's death would have jostled its family of comets, throwing them into one another's paths and creating a fresh supply of dust. A similar fate may well await the Sun 5 billion years from now. The researchers reported their findings in the March 1 *Astrophysical Journal Letters*. — **R. T.**

Titan's Black Sea

A body of liquid as big as a sea has turned up in a radar image of Saturn's largest moon, Titan. The Cassini spacecraft took the image during a February 22 flyby. The liquid covers at least 39,000 square miles (100,000 square kilometers), making it more than 20-percent larger than North America's biggest body of water, Lake Superior.

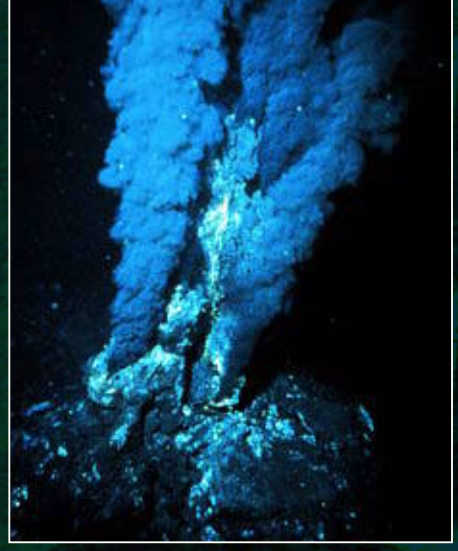
So far, scientists have found most of Titan's lakes near its north pole (on the swath's right edge). Depressions become more numerous and more frequently filled with dark material as you approach the pole. Scientists interpret the smooth, dark regions to be lakes of liquid methane, liquid ethane, or a combination of the two.

The image's final section contains the biggest lakes. Planetary scientists speak of the largest one (at far right) as a full-fledged sea. It covers at least 0.12 percent of the moon's surface. The Black Sea, Earth's largest inland body of water, covers only 0.085 percent of our planet's surface. — **R. T.**



LAND O' LAKES. **This radar swath, taken during the Cassini spacecraft's February 22 flyby of Titan, reveals a vast sea of liquid hydrocarbons at far right.** NASA/JPL

Earth's deadly future



"BLACK SMOKERS" are bastions of life at hydrothermal vents in today's oceans. They get their names from the soot-like look of the mineral-rich material they eject. NOAA

A brightening Sun will boil the seas and bake the continents a billion years from now. But that's nothing compared with what we can expect further down the road. /// **BY RICHARD TALCOTT**

A BILLION YEARS FROM NOW, the Sun's increasing luminosity will have boiled off most of Earth's water. In this view, water exists only in deep ocean trenches, where thermophilic bacteria cling to life. LYNETTE COOK

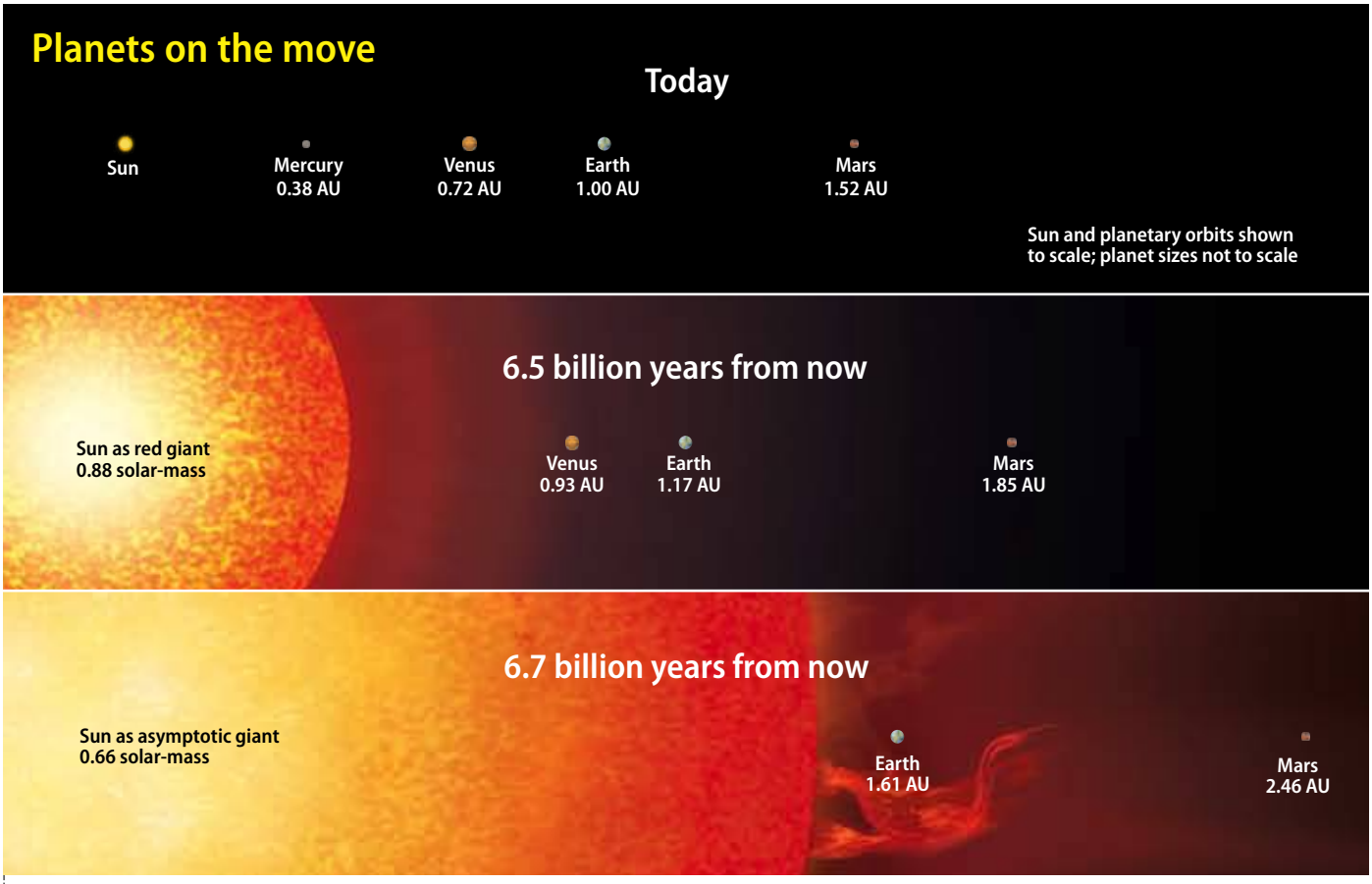
The first things to go will be Earth's glaciers and polar ice caps. Warming surface temperatures will turn ice to water, leading to a slow but steady rise in sea levels. But it doesn't stop there. Eventually, temperatures will rise high enough for seawater to boil away, leaving Earth bereft of this vital substance. With that, life on our world will need to relocate underground or emigrate from our home planet.

This apocalyptic scenario is more than an inconvenient truth — it's our inevitable destiny. And it has nothing to do with changes humans may work on our fragile environment. The agent for this transformation is far beyond our control. The culprit: our current life-sustaining source of heat and energy, the Sun.

Ask most people familiar with astronomy when to expect this coming apocalypse, and you'll hear answers of around 5 billion years — once the Sun swells into a red giant. But the end is nearer than that. The Sun is currently growing brighter, and has been since the day it was born.

Life on the main sequence

When the Sun was a baby, it was rather miserly by today's standards. It emitted roughly 30-percent less energy then than it does now. The Sun officially became a star when it started fusing



AS THE SUN AGES, it will lose some of its mass. This trend will accelerate when it becomes a red giant, and grow even greater when it swells into an asymptotic-giant-branch star. This mass loss will cause the orbits of the planets to migrate outward. *ASTRONOMY:* ROEN KELLY

hydrogen into helium in its core. These nuclear reactions release energy according to Einstein's famous equation: $E=mc^2$. This energy source defines any star's main sequence life — where it spends the vast majority of its days.

We tend to think of a main sequence star like the Sun as constant, but it's not. It maintains what astronomers call hydrostatic equilibrium — the outward pressure exerted by the core's hot gas balances the inward crush of gravity. If the Sun's central temperature were to drop slightly, for example, the gas pressure would also fall. Gravity then would force our star to contract and heat up, restoring its equilibrium.

The Sun started life as a uniform mix of approximately 73-percent hydrogen, 25-percent helium, and 2-percent heavier elements, by mass. The outer parts of the Sun still maintain that balance. But in the core, where nuclear fusion rules, helium levels continuously rise. Since the Sun's birth, about 5 percent of its total mass has been converted into helium.

Richard Talcott *is a senior editor of* Astronomy.

And that's the rub. The nuclear reactions in the Sun's core essentially convert four hydrogen atoms into one helium atom. Gas pressure, however, depends in part on the number of particles in the gas. The ongoing fusion reduces the number of particles, so the pressure drops. To maintain hydrostatic equilibrium, the Sun must compensate. The core shrinks, raising both the temperature and density. That, in turn, increases the rate of nuclear reactions, and the Sun generates even more energy.

These changes operate slowly. Although a hundred million years may sound like a long time, for the Sun, it's a blip on the radar screen, representing 1 percent of its life span. And in a hundred million years, the Sun's luminosity rises less than 1 percent. The energy increase prompts the Sun to expand at a comparably lethargic pace. Its diameter grows at about the same rate as human fingernails: 1 to 2 inches per year.

Crystal-ball gazing

If the Sun is warmer now than it was in the past, what were conditions like on Earth a few billion years ago? Surprisingly, they weren't much, if any, colder. That's good news as far as life is concerned. The first single-cell organisms arose some 3.5 billion years ago, and they presumably required liquid water. But the Sun wasn't hot enough by itself to melt terrestrial ice until roughly 2 billion years ago.

We can thank our lucky stars for the greenhouse effect. The presence of water vapor and carbon dioxide in the atmosphere warms our planet well above what it would otherwise be. Even today, Earth is some 60° Fahrenheit (33° Celsius) warmer than it would be without greenhouse warming. In the distant past, when Earth's interior was hotter and volcanic eruptions likely belched significantly more greenhouse gases into the atmosphere, the effect would have been greater.

The push to higher solar luminosities continues. Roughly 1 to 2 billion years from now, Earth's surface temperature will approach the point of no return, when water will start evaporating and herald an end to above-ground life.

Several unknowns affect the timing. Most important: The fraction of greenhouse

gases the atmosphere will contain. Most scientists expect the level of atmospheric carbon dioxide to drop in the distant future. This will come about as photosynthetic organisms extract carbon dioxide from the atmosphere and weathering incorporates some of it into silicate rocks, which then are subducted into the mantle.

As the oceans start to evaporate, the Sun's high-energy ultraviolet radiation will break the water molecules into their constituents, hydrogen and oxygen. The lightweight hydrogen gas will escape Earth's gravitational hold and bleed into space. It might take another billion years for ocean water to disappear completely, but by then, any remaining life will have had to make other plans.

One viable option might be Mars. As Earth becomes too warm for most life to survive, the Red Planet should be getting balmy. If humans can make it till then, Mars would offer some attractive real estate.

Into the deep future

To this distant point, the Sun and Earth have taken nearly opposite paths. Even a billion or two years from now, the Sun will look basically the same on the outside as it does now — a little bigger and brighter, but still recognizable. The Sun's internal structure, however, will have changed markedly. Its center will be largely helium, although lots of hydrogen will exist in the core. The hydrogen continues to fuse into helium and add to that element's growing abundance.

For Earth, on the other hand, the surface would hardly be recognizable. Our "pale blue dot" will be more of a muted brown, and blistering temperatures will make it uninhabitable. But the deep interior won't see much effect. Although it will have cooled modestly as the total mass of radioactive elements decreases, a 21st-century geologist would still recognize it.

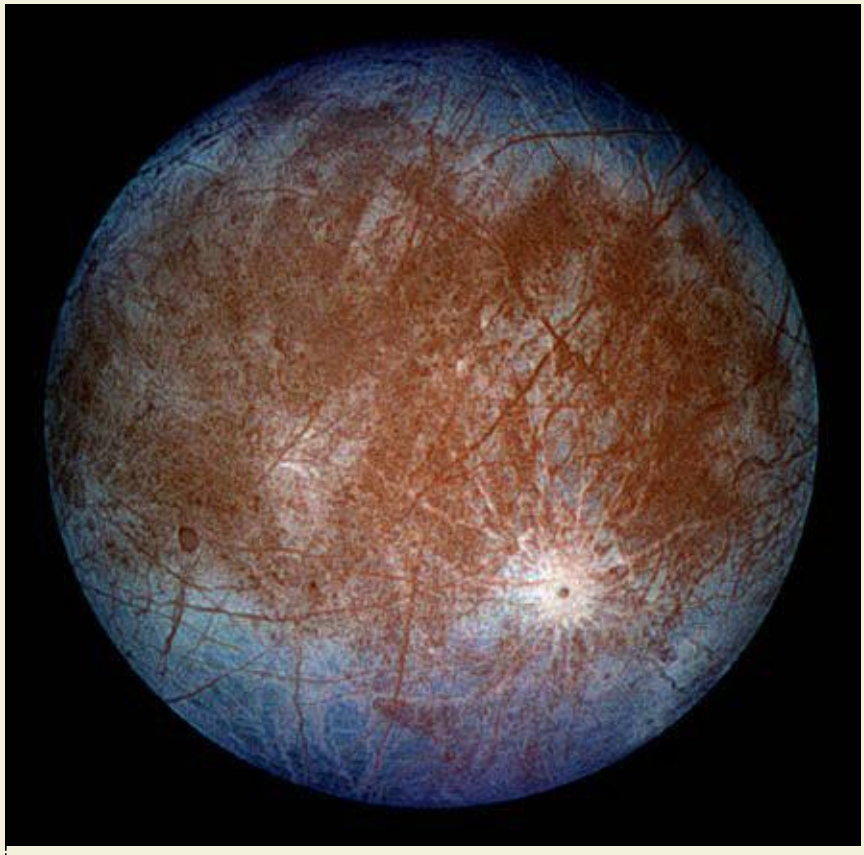
But as time continues to march on, changes in the Sun and the rest of the solar system will become more pronounced. The real changes start roughly 5 billion years from now, when the Sun exhausts the hydrogen fuel in its core and prepares to leave the main sequence. As the Sun takes its first tentative steps into old age, it will shine some 70-percent brighter than it does now. That won't last long, however.

The Sun's inner core then will contain only helium. It'll be hot (some 50 million Kelvin) and dense (10,000 times the density of water) there, but not extreme enough to ignite helium. Meanwhile, hydrogen in the outer core will continue to burn.

With no source of energy at the center, the core will contract and heat up. Like adding gasoline to a fire, the increased heat will cause the hydrogen-burning shell to kick into overdrive. As the Sun's luminosity jumps, the overlying layers will expand and cool. The star will be on its way to becoming a red giant.

Monster star

It will take the Sun between 1 and 1.5 billion years to evolve from the close of its main sequence life to a full-fledged red giant. By



ICY EUROPA could prove to be a watery haven in the distant future, when increasing solar radiation will render the inner planets uninhabitable. NASA/JPL

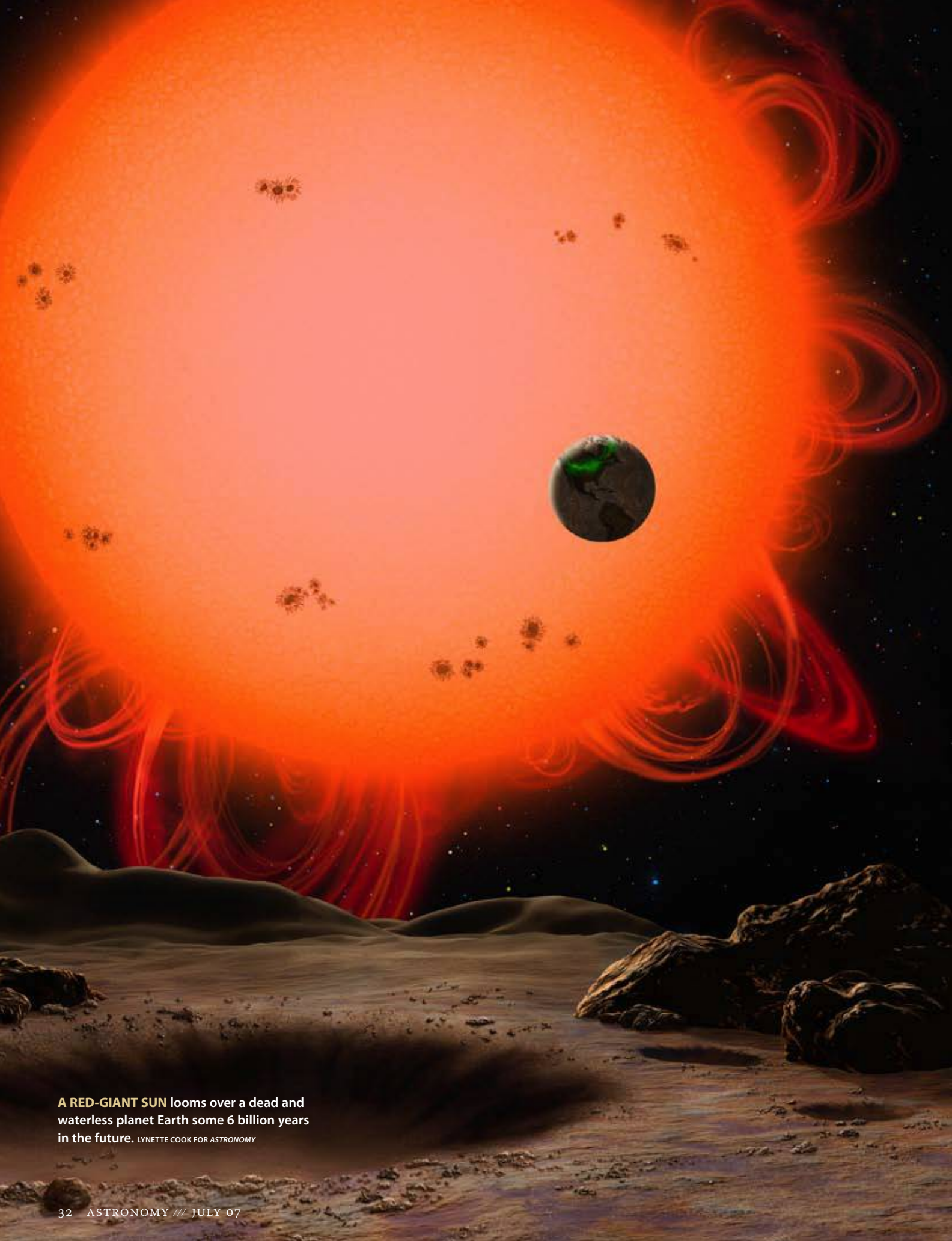
LOCATION, LOCATION, LOCATION

When the South Pole feels more like the Amazon jungle a few billion years from now, any life on Earth will be looking for a way out. The Sun's increasing luminosity will render Earth uninhabitable, and worried eyes will look skyward.

In a reversal of science-fiction proportions, the first stop may well be Mars. Unlike H. G. Wells' classic novel, in which dying Martians looked longingly toward a more hospitable Earth, earthlings may decide to head for cooler martian climes. Mars has a distinct advantage: Not only will it likely serve as humans' first permanent outpost in the solar system, but it also holds the promise of being clement for an extended period.

But even Mars will grow too hot once the Sun becomes a red giant. Then, the only reasonable outposts will be on the moons of the gas-giant planets. Several of them — including Jupiter's Io, Europa, and Ganymede, and Saturn's Enceladus, Rhea, and Dione — already come with huge complements of ice. Raise the Sun's temperature significantly, and all may afford ocean-front property at some future point.

But the reality of the Sun's demise is that by the time Jupiter or Saturn become viable abodes, any surviving civilization should seek other solar systems. After several billion years of calling Sol home, a few million extra years won't seem like much. It will be time to become citizens of the galaxy. — *R. T.*



A RED-GIANT SUN looms over a dead and waterless planet Earth some 6 billion years in the future. LYNETTE COOK FOR *ASTRONOMY*

then, its surface temperature will have dropped to around 3,500 K, just over half of what it was on the main sequence. The cool surface will mean the star radiates most of its energy at longer wavelengths, in the red part of the spectrum. Still, the Sun will put out 1,000 times more energy than today.

To release this much energy from a cooler surface requires the Sun to swell dramatically. As a red giant, it will appear 100 times bigger than today, taking it beyond Mercury's orbit and swallowing the innermost planet. If any people were to visit Earth on a spaceship from the more temperate outer solar system, they would see the Sun as a bloated red sphere spanning some 50° of the sky. If our planet still rotated once every 24 hours, it would take the Sun more than 3 hours to rise and set. In reality, Earth's rotation will have slowed significantly by then, lengthening sunrise and sunset further.

In the red giant's distended outer layers, gravity will be so weak that the solar wind will blow a million times stronger than it does today. During the course of its red-giant phase, the Sun will lose approximately 10 percent of its total mass.

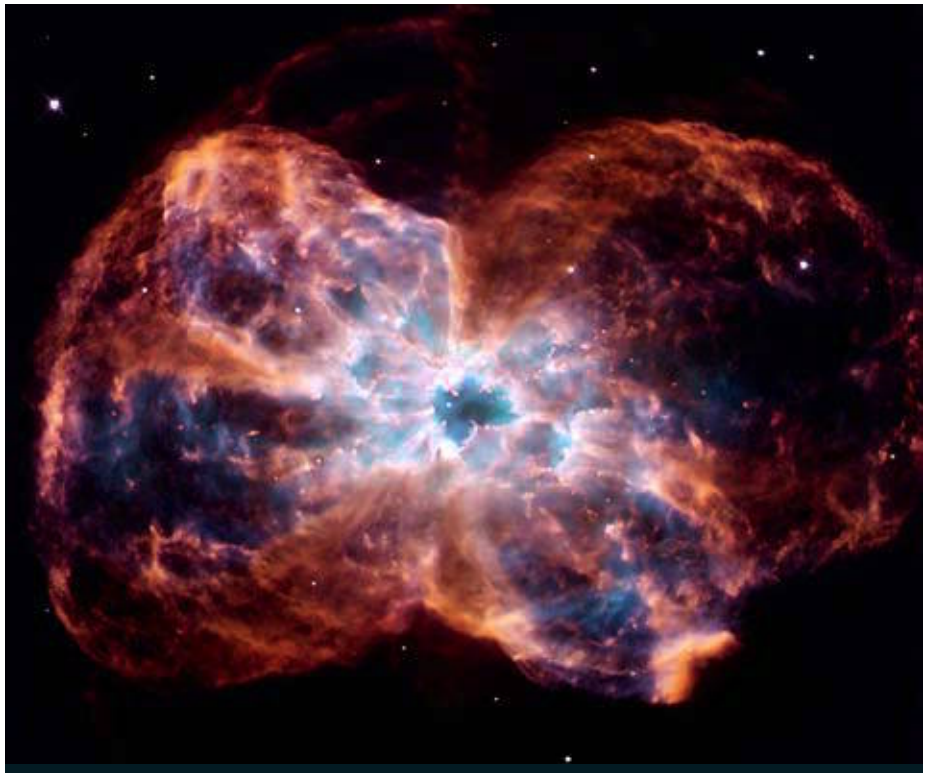
This gradual mass loss will reduce the Sun's overall gravitational pull, so it no longer will hold the planets as tightly. The planets will spiral outward a bit — except for Mercury, of course, which already will have succumbed to the Sun's appetite.

As hydrogen continues burning in a shell, it'll dump more helium "ash" onto the inner core. Eventually, the temperature at the center will rise to 100 million K — hot enough to ignite helium. The Sun will tap into this second energy source with a vengeance, fusing helium into carbon and some oxygen in its core while still fusing hydrogen to helium in a surrounding shell.

Ironically, the initiation of helium fusion will lower the Sun's luminosity as it causes the core to expand and cool. The star as a whole will shrink, and its surface will warm. It will stay in this stable configuration for approximately 100 million years. Two bright stars visible from Earth — Aldebaran and Arcturus — are at this stage of evolution now.

Supersize me

As with all nuclear reactions, a small temperature increase causes a big jump in the reaction rate. That's why the Sun will burn through its helium fuel so rapidly. Then, it's déjà vu all over again. Carbon ash will build up in the center, surrounded by a helium-burning shell which, in turn, will be surrounded by a hydrogen-burning shell. Once more, the core will contract, heating the interior and spiking the nuclear-reaction rates. The star swells again; but this time, it'll grow even bigger and more luminous than on the first go-round. It is now an "asymptotic-giant-branch star."



WHEN THE SUN DIES, it will puff off its outer layers in a final blaze of glory. The resulting planetary nebula, like NGC 2440 seen here, will last about 50,000 years. NASA/ESA/K. NOLL (STScI)

At the height of this phase, the Sun will be 500 times its current diameter and swell beyond the current orbit of Mars. Its outer layers will claim their second victim as they swallow Venus. But the Sun also loses mass at a greater rate this time around, turning the solar wind into a full-blown hurricane. The Sun's mass will drop to two-thirds of what it is now, and Earth's orbit will grow by approximately 60 percent.

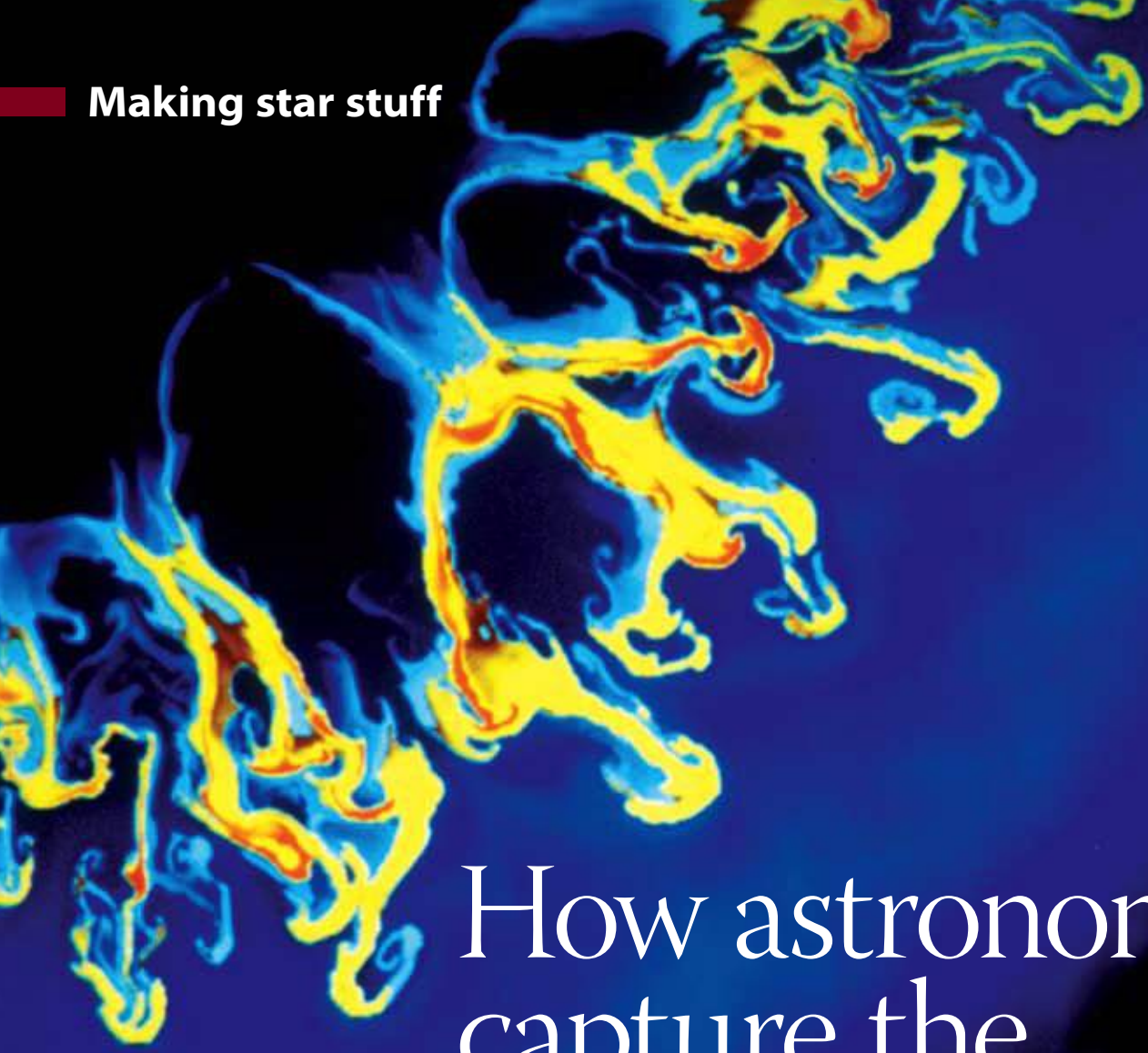
Current computer models can't tell whether Earth will survive the onslaught or not — it looks to be a close call. Mars should make it easily, although its days of relative tranquility will be long over. The best place to be could be on one of the moons of the outer planets. They may enjoy a brief period of springlike weather. And with large stores of ice currently on some of them, precious water could be plentiful.

The Sun's internal instability during this asymptotic-giant-branch stage will cause our star to pulsate with a period measured in hundreds of days. It will be a Mira variable star, named after the prototype star in the constellation Cetus.

In just a few tens of thousands of years, the Sun will puff off its outer layers. The Sun's core, made of carbon and oxygen, will be left behind as a white-dwarf star. The star then will contain more than half the Sun's current mass compressed into a sphere the size of Earth — a density equivalent to crushing a car to the size of a grape.

The white dwarf will have an initial temperature of 100,000 K, so it'll emit lots of ultraviolet light. This high-energy radiation will energize the expanding shell that was previously the Sun's outer layers, causing it to glow. This planetary nebula will light up for about 50,000 years before the shell dissipates into the interstellar medium. Meanwhile, the remnant white dwarf will slowly but steadily cool off, eventually extinguishing the light that nurtured billions of years of life in the solar system.

ONLINE EXTRA To watch a simulation of the Sun's evolution in the distant future, visit www.astronomy.com/toc.



TWO HOURS after a computer-simulated supernova, the blast wave starts to emerge into the dying star's hydrogen envelope. Growing instabilities create finger-like projections that mix heavy elements into the star's outer layer. Using powerful lasers, scientists can glimpse microscopic versions of this process.
LAWRENCE LIVERMORE NATIONAL LABORATORY (LLNL)

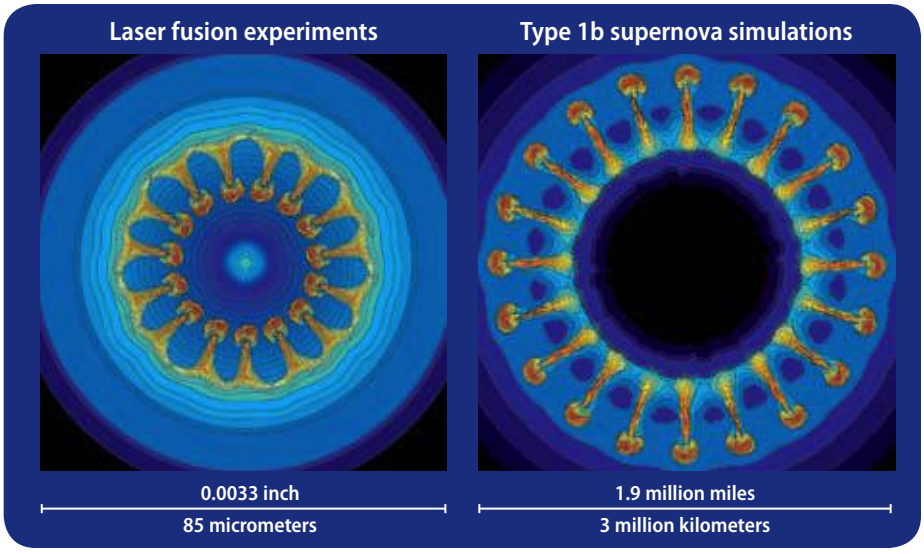
How astronomers capture the universe in a test tube

New simulations and lab experiments unmask supernovae, black holes, and the universe's first moments. /// **BY STEVE NADIS**

Supernovae explode and violent gamma-ray jets shoot through space far from Earth. Astronomers may catch a few photons from one of these outbursts — if they notice anything at all. But then, it's over. Not too long ago, that would have been the end of the story. Astronomers would have little recourse other than to get their telescopes ready, wait — and hope someone was looking the right way, with the right instrument, when the next event blew.

Now, though, researchers have another option. They can reproduce portions of astrophysical phenomena in controlled settings — laboratories — to patiently sort out the basic physics. This new approach is "a sea change in the way we do astrophysics," says University of Rochester astronomer Adam Frank. "For the first time, we can bring stellar conditions down to Earth."

Astronomers now use lasers, powerful magnets, plasma experiments, and other tools new to their trade to complement the data obtained from telescopes. Scientists are just beginning to explore this new specialty, called "laboratory astrophysics" — standing alongside observation, theory, and computational astrophysics.



LASER EXPERIMENTS that implode tiny hydrogen-fuel capsules (left) and computer simulations of supernovae develop similar mushroom-like fingers of turbulent plasma. LLNL

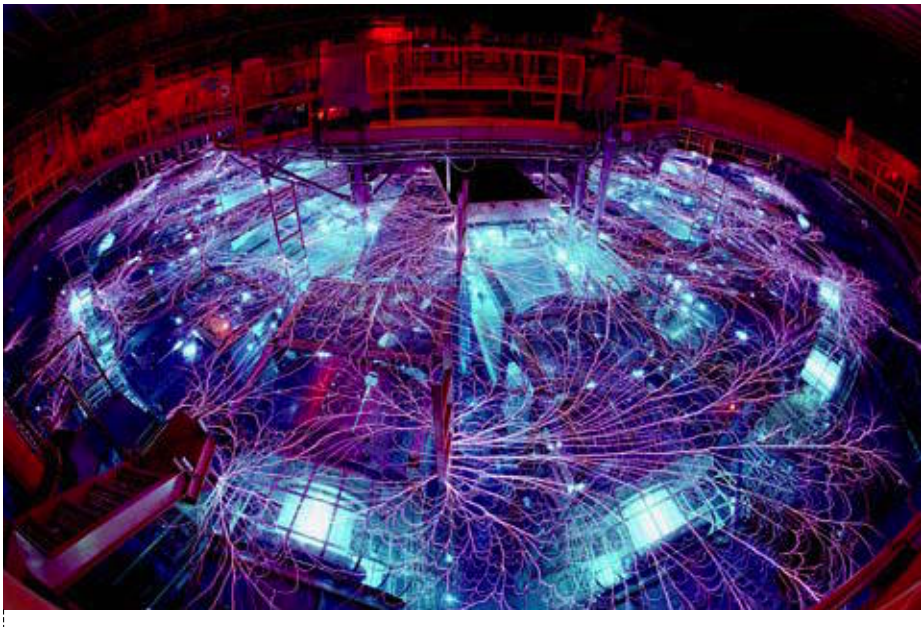
The birth of an idea

In 1995, Bruce Remington was looking at pictures from computer simulations of a supernova explosion when he nearly fell out of his seat. The images of gas mixing were almost identical to ones he'd seen of turbulent mixing of plasma in laser fusion experiments. Remington, a physicist at Lawrence Livermore National Laboratory in Livermore, California, surmised such experiments could shed light on astrophysical phenomena like supernovae, provided results obtained at a fraction of a centimeter could be scaled up nearly a trillion-fold.

Working with Livermore theorist Dmitri Ryutov, Remington showed that the same physics applies at both microscopic and astronomical scales. This finding helped open the door to laboratory astrophysics. "We grabbed onto this idea at the right moment," Remington says. "People were just waiting for good problems to work on."

The problem he took up first related to instabilities in supernova explosions, which bear similarities to plasma instabilities he encountered in his fusion research. Remington immediately asked University of Arizona supernova specialist David Arnett to join him in the lab. Simulating supernova conditions with a laser, Arnett says, "can take some of the guesswork out of astronomy. The laser gives us a cross-check to make sure our theories and computer simulations are right."

Other researchers have used the Z machine at Sandia National Laboratories in Albuquerque, New Mexico; the Omega laser at the University of Rochester in Rochester, New York; and other instruments, to reproduce aspects of astrophysical processes. "We can't create a supernova or an astrophysical jet, but we can create little pieces of those phenomena in a rigorously scaled setting," Remington explains.

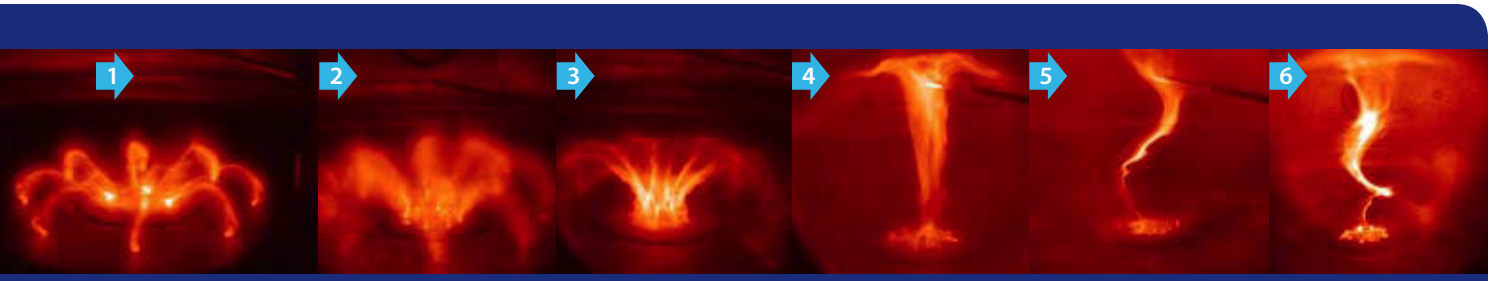


ELECTRICAL DISCHARGES play across the surface of Sandia National Laboratory's Z machine. The world's most powerful X-ray source, the Z machine is helping scientists study a variety of astrophysical problems. SANDIA NATIONAL LABORATORIES/RANDY MONTOYA

Inside the giants

Scientists trying to probe the interiors of Jupiter, Saturn, and other gas-giant planets face a familiar problem in astronomy: "We can't see the interiors of these planets, only their surfaces," says Los Alamos National Laboratory astrophysicist Didier Saumon.

Hydrogen, with smaller amounts of helium and heavier elements, compose the giant planets. Each added layer of hydrogen squeezes lower layers, until the central pressure reaches 50 million Earth atmospheres and temperatures peak at 36,000° Fahrenheit



LABORATORY-CREATED PLASMA JETS give scientists clues about how astrophysical jets — like those from black holes and infant stars — form. Arching "spider legs" form first (1). They then converge (2, 3) and launch a 13-inch-long (33 centimeters) jet (4). When the jet becomes too long, instabilities kink the flow (5, 6). Lab jets mimic features of those found in stars and galaxies. PAUL BELLAN (CALTECH)

(20,000° Celsius). Scientists don't know much about hydrogen's properties under such conditions. But, Saumon notes, "We've been able to reproduce some of those conditions in the lab."

To this end, he's joined forces with physicist Marcus Knudson of Sandia National Laboratories. Knudson uses the powerful magnets of Sandia's Z machine to accelerate a small aluminum plate to 76,000 mph (122,000 km/h) in less than a second. The plate slams into a capsule containing deuterium, a heavy hydrogen isotope. The impact's shock waves heat the deuterium to 54,000° F (30,000° C) while compressing it to million-atmosphere pressures.

Results from such experiments help Saumon and others model the gas-giant planets. We know Jupiter's average density from its total mass and size. By knowing how hydrogen compresses under different conditions, researchers can determine the amount of heavy elements — like iron — thrown into the mix.

Saumon concludes Jupiter consists of about 10-percent heavy elements by mass. But conditions produced by the Z machine aren't the same as those found within Jupiter. An upgraded Z machine should begin operations late this year. It will produce even higher pressures and permit more accurate experiments.

Launching a jet

Astrophysics was not on Paul Bellan's mind in the 1990s, when he began tinkering with a device called a planar spheromak. The California Institute of Technology physicist was focused on confining plasmas with magnets to further the goal of controlled nuclear fusion. A "plasma gun" he was using at the time made curious jet-like features. The more he read, the more he became convinced his tiny jets resembled the gigantic ones of astrophysics.

His laboratory jets are just 13 inches long (33 centimeters) and last 10 microseconds from start to finish. Astrophysical jets, by contrast, can extend millions of light-years and survive for eons. Yet, he says, the physics must be "scalable" because astrophysical jets exist over a vast size range, from those associated with individual star formation to jets a billion times bigger blasting from active galaxies.

> "WE CAN TRY something, adjust a few knobs, and try it again."
> — *Paul Bellan*

"The scale of the jets is not a problem at all," agrees Jet Propulsion Laboratory astrophysicist David Meier. Bellan's major accomplishment, says Meier, has been to demonstrate a mechanism for how jets lift off an object's surface and align into a narrow beam. So far, Bellan hasn't shown how these jets accelerate to super speeds where kinetic, rather than magnetic, energy dominates their flow.

In Bellan's experiments, magnetic forces squeeze plasma into a narrow plume and accelerate it along magnetic field lines to form a jet. Their flow pattern, alignment, and shape show striking similarities to astrophysical jets, Bellan says. He has plans to make his jets 5 times longer by boosting his power supply. He says he can make them faster by using higher currents or lowering the system's gas density.

Bellan is more interested in learning than setting speed records. Data are often spotty in astrophysics, he says. "In the lab, we can ask detailed questions about jets. We can try something, adjust a few knobs, and try it again."

Neutron stars fit to burst

At the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University, physicist Hendrik Schatz is studying nuclear reactions that occur in "superbursts" on the surfaces of neutron stars.

During the past decade, astronomers have learned that neutron stars in tight binaries with dwarf stars can undergo violent surface explosions. These exotic thermonuclear reactions may not occur elsewhere in the universe.

Researchers believe it all starts with a conventional X-ray burst. These occur every few hours as hydrogen and helium gas drawn from its stellar companion accretes on the neutron star. The gas layer grows hotter as more matter accumulates and pressures rise. Eventually, the accreted matter begins nuclear fusion. The neutron star flares with a 10-second spurt of X rays.

"The ashes from normal X-ray bursts contain the fuel that powers the superbursts," explains Schatz. Repeated normal bursts create a residue of fusion by-products — carbon and other "heavy" elements. As they build up, temperatures and pressures gradually rise. Every year or two, the "ash" reaches a depth of up to 330 feet (100 meters). At this point, says Schatz, the

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Steve Nadis, *a frequent* Astronomy *contributor, keeps tabs on astrophysics advances from his home in Cambridge, Massachusetts.*

NASA'S CHANDRA OBSERVATORY detected more than 2,000 X-ray sources (the bright dots) near the Milky Way Galaxy's central black hole. Computer models predict the X-ray properties of gases around these high-energy objects, many of which are accreting binary systems. But experiments using the Z machine provide important reality checks for calculated spectra. NASA/CXC/MIT/F. K. BAGANOFF ET AL.

heavy-element layer itself begins undergoing nuclear fusion, creating a superburst.

"We don't know what those ashes are, and that's what we're trying to figure out in the lab." The ashes form either as nuclei capture protons or as neutrons decay. A long sequence of reactions leads from carbon (with 6 protons) to tellurium (52 protons). "But," Schatz explains, "all parts of this chain are not equally important."

He focuses on critical bottlenecks that set the time scale for the entire process. This, in turn, dictates how much carbon survives to power the next superburst.

The X-ray factory

The same general process powers both stars and thermonuclear weapons. So, it's not surprising that devices designed to test these weapons may shed some light on astrophysical phenomena. Scientists from Lawrence Livermore and Sandia national laboratories, for example, are using Sandia's Z machine, the world's most powerful X-ray generator, to understand the universe's most powerful X-ray sources.

Black holes, neutron stars, and white dwarfs all accrete matter, which heats up and emits X rays. "About half the X-ray emissions in the universe come from accretion-powered objects," explains Livermore physicist Mark Foord. "We can learn about these objects — and estimate their sizes and temperatures — by seeing how the radiation they emit affects nearby matter."

In his experiments, the Z machine stands in for an astrophysical source. The device shoots out an X-ray beam that heats a sample of material to millions of degrees in a few billionths of a second. Researchers record and analyze the X rays emitted by the superhot, ionized sample.

In the first experiments, Foord's team used iron samples because that element is so abundant in the gases around accreting objects. More recent experiments have featured sodium, fluorine, and neon.

By studying the X-ray emissions of these elements under controlled conditions, the Livermore-Sandia team can help astronomers interpret X-ray spectra collected by the Chandra X-ray Observatory, XMM-Newton satellite, and other instruments.

"The spectral lines tell you about the conditions in the plasma around these high-luminosity objects," explains Oxford University physicist Steven Rose. Astrophysicists use computer models, or codes, to predict how the different ionization states of iron and other materials are distributed in gases around X-ray-emitting objects. Rose says the Sandia results yield a pretty good fit with predictions. "It gives us faith that they're not too far off the mark."

Stardust memories

It's been said that we're made of stardust, but how, exactly, is stardust made? This question — which concerns the origin of the elements — is one of the biggest in science. Astronomers believe that fusion in stellar cores and violent supernovae synthesize heavy elements. But the details are sketchy. For example, when and where in a supernova does this synthesis take place?

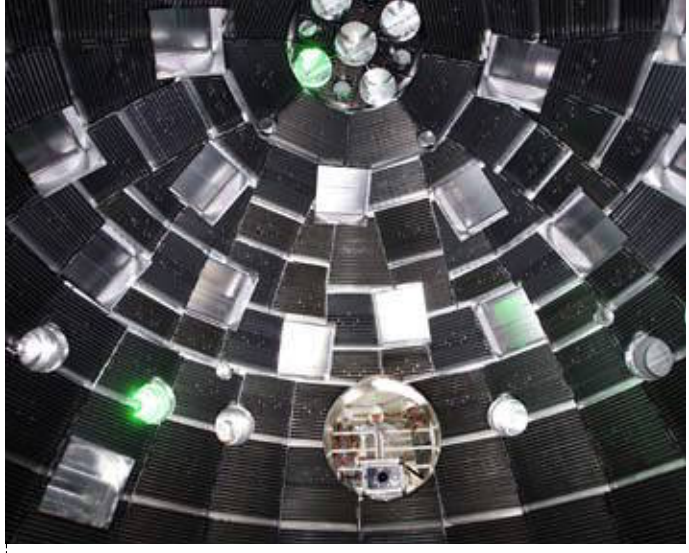
"The heaviest elements are made from unstable radioactive species that have never been seen," says University of Arizona astrophysicist Adam Burrows. "If we don't understand the properties of the unstable nuclei, we can't understand the patterns of production we see in nature."

So far, calculations based on supernova models don't match observed abundance patterns. To improve these models, says Burrows, we need to know how these unstable nuclei decay and how fast they decay. Nuclear-physics experiments provide crucial "ground truth" for processes we can't otherwise see in detail.

In recent experiments at the NSCL, Schatz, Paul Hosmer, and their colleagues created an exotic isotope by splattering argon gas against a beryllium plate. What they produced is nickel-78, an unstable nucleus whose decay plays a role in heating a supernova's expanding gas envelope. They

SANDIA NATIONAL LABORATORIES/RANDY MONTOYA

SANDIA'S MARCUS KNUDSON holds a flyer plate. The Z machine accelerates these flyers to high speeds. When they strike a target, the impact's shock waves heat and compress the target material, briefly producing conditions similar to those inside Jupiter.



UNIV. OF CALIFORNIA/LLNL/DEPARTMENT OF ENERGY

IN THE TARGET CHAMBER at the National Ignition Facility, 192 high-power lasers will converge onto a pencil-eraser-sized target containing hydrogen isotopes. Scientists hope the imploding target will undergo nuclear fusion — the process that powers stars.

measured nickel-78's half-life at 110 milliseconds, less than a quarter of the value scientists had predicted.

"This really accelerates the process of heavy-element synthesis," Schatz says. He plans to measure the lifetimes of other critical nuclei — up to mass number 130 — at the NSCL. Then he'll shift to the yet-to-be-built Rare Isotope Accelerator to study heavier elements.

"We need data because current models are too ambiguous," Schatz says. "We can't measure everything, but if we nail down a few points on the curve, we can put more trust in our theoretical predictions."

The Big Bang machine

What was matter like a millionth of a second after the Big Bang? Until recently, inquiries like that were limited to theoretical speculation. But in 2005, physicists working at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory think they got a glimpse of matter in just such a state.

To cosmologists, RHIC, the world's highest-energy particle collider, is a bit like a time machine. The higher the temperatures and energy densities it produces, the further back in time scientists can peer. At RHIC, scientists smash beams of gold nuclei into each other at close to light-speed. When the nuclei hit, the nearly 200 neutrons and protons tightly held in each nucleus break into their constituents — quarks and the gluons that bind them.

For a brief moment — 10^{-22} second to be exact — the collision generates temperatures of more than a trillion degrees and achieves matter densities comparable to a neutron star's core. Quarks and gluons roam freely in this state. On the subatomic scale, RHIC recreates an essential moment in cosmic history — the so-called quark-hadron phase transition.

Physicists thought that under such extreme conditions, approximating those believed to exist when the universe was a microsecond old, matter would form a hot gas called a "quark-gluon plasma." This is exactly what Brookhaven physicist Thomas Ludlam and his team think they saw — but, to their surprise, it behaved more like a liquid than a gas.

> "WE NEED data because current models are too ambiguous." — *Hendrik Schatz*

Jets of high-energy quarks flew from the plasma's dense outer portion, but not in the even denser, central region. "It's like putting a fire hose in a swimming pool," Ludlam explains. "You don't see a jet of water."

The next big step for physicists should come late this year, when the Large Hadron Collider (LHC) begins operating at the European Organization for Nuclear Research (CERN) in Geneva. The LHC should smash nuclei with 30 times RHIC's energy and reach temperatures twice as high. "We'll see if, at these higher temperatures, things behave more like the gas we predicted," Ludlam says.

Laboratory futures

High-energy physics experiments can take us to within a split second of the universe's birth. But what about the universe's future? Can these laboratory experiments shed light on that as well?

Remington thinks they can. Astronomers believe dark energy will increasingly dominate the future, and most of what we know about dark energy's existence comes from observations of type Ia supernovae. But there's still a lot to learn about these fiery star deaths. Experiments, for example, could probe the physics surrounding the transition from burning to detonation. In so doing, says Remington, "We can shore up our expansion-of-the-universe calculation."

New devices will soon come online. The upgraded Z machine should be running this year, and, in 2009, the National Ignition Facility, the world's highest-energy laser, should be ready. Although a site for the Rare Isotope Accelerator has yet to be selected, the facility is a high priority for particle physicists.

Together, these massive machines may take the emerging field of laboratory astrophysics to a whole new level.

ONLINE EXTRA Visit www.astronomy.com/toc to watch movies of Paul Bellan's plasma-jet experiments.

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About Your Professor

Professor Arthur T. Benjamin is Professor of Mathematics at Harvey Mudd College, where he has taught sin 1989. He earned a B.Sc. from Carnegie Mellon University in 1983 and a Ph.D. in Mathematical Sciences from Johns Hopkins University in 1989. The Mathematical Association of America honored him with regional and national awards for distinguished teaching in 1999 and 2000 and named him the George Pólya Lecturer for 2006–08.

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The asteroid collectors

The Minor Planet Center tracks hundreds of thousands of asteroids — and one may be heading our way. /// BY BRIAN G. MARSDEN

By June 18, 1998, Charles W. Juels, a retired physician and amateur astronomer in Fountain Hills, Arizona, had completed 43 asteroid observations with his 10-inch reflector over 2 nights. The asteroids were distant and faint, ranging in magnitude from 12 to 16. Capturing them required 1-minute CCD camera exposures.

Juels had done everything so far that would allow him to report his data to the Minor Planet Center (MPC) in Cambridge, Massachusetts. He photographed each object two to three times at 30-minute intervals over 2 consecutive nights, thus providing the multiple observations my colleagues and I at the MPC would need to calculate the objects' orbits and possibly confirm the discovery of a previously unknown asteroid.

Juels' next move would be to e-mail his observations to the MPC. There, we determined that all the asteroids Juels observed had already been discovered. But Juels was undeterred. In January 1999, he sent the MPC fresh observations of the 18th-magnitude asteroid 1997 YO that enabled us to pin down the object's orbit and assign it the sequential number 19369.

It wouldn't be long, however, before Juels succeeded in joining the exclusive club of amateur astronomers who discover and name new asteroids — in Juels' case, hundreds of them.

Brian G. Marsden *is the director emeritus of the Minor Planet Center. The asteroid 1877 Marsden is named in his honor.*

Minor terminology

The terms "asteroid" and "minor planet" are synonymous. Until recently, the International Astronomical Union (IAU) preferred minor planet because it clearly distinguished such a body from a "major planet" like Earth or Mars. However, the IAU's recent introduction of "dwarf planet" for Pluto relegated asteroids and comets to the status of "small solar system bodies."

The confusion about what to call asteroids started in 1801, when Italian astronomer Giuseppe Piazzi (1746–1826) discovered what he dubbed "the eighth planet" between Mars and Jupiter. Piazzi named it Ceres, after the Roman corn goddess. The following year, astronomers discovered a body rather similar to Ceres and named it Pallas. William Herschel proposed that they be termed "asteroids," roughly translating to "star-like in appearance." Piazzi was not content for Ceres to be merely star-like, and proposed to classify Ceres and Pallas as "planetoids."

Neither term caught on until the middle of the 19th century, when astronomers began to discover the objects in greater numbers. The term minor planet became standard in England, with corresponding translations into other languages in Europe. At the same time, *The Astronomical Journal* — the leading astronomy publication in the United States — consistently used "asteroid."

The indecision continues today: In 2006, the IAU upgraded Ceres to "dwarf-planet" status. Meanwhile, as the debate over the

WITH INVALUABLE HELP from amateur observers around the world, the Minor Planet Center discovers and catalogs new asteroids much as butterfly collectors catch and mount new species. PHOTOGRAPHY: *ASTRONOMY*: WILLIAM ZUBACK; ASTEROID IMAGES: NASA/JPL-CALTECH, EXCEPT ITOKAWA (JAXA)

demotion of Pluto to dwarf planet continues, we at the MPC — which I headed from 1978 to 2006 — still attend to the business of cataloging the ever-increasing host of small solar system bodies. To date, our catalog includes some 155,368 numbered minor planets and more than 45 million documented minor-planet observations. For all the asteroids discovered, we're really just getting started: It's estimated the solar system holds millions of as-yet unknown minor planets. The smallest asteroids known are less than 10 meters (33 feet) across, while the largest are hundreds of kilometers wide.

Asteroids by the numbers

In the 1850s, sky surveys revealed 4 dozen new minor planets between the orbits of Mars and Jupiter — the realm of the "main belt" asteroids. By the end of the century, the inventory grew to nearly 500. Astronomers increasingly used photography to find minor planets, which would show up as short streaks of light on long-exposure photographic plates of the sky.

Keeping track of these new members of the solar system became progressively more difficult. Astronomers cataloged asteroids in the order of their discoveries.

But the delay between exposing and examining photographs meant that discoveries could get out of sequence. They might be numbered based on how fast people developed their plates instead of when they actually photographed the objects. Photographic delays also meant that by the time an observer recognized an asteroid, there was often little or no hope of finding it again. One might have to wait for someone else to observe the same object years later and link it to the previous sighting — a process called "making an identification." Identifications make it easier for us to calculate minor-planet orbits.

Making provisions

With the number of asteroid observations increasing, astronomers needed a way to keep track of the objects until they could calculate the orbits — the key step in confirming a new asteroid. So astronomers adopted a system of "provisional designations," or temporary naming, of minor planets to preserve the date and order of their discoveries until orbits could be nailed down.

Beginning in 1925, provisional designations consisted of the year, two upper-case letters, and, if necessary, an additional subscripted number. Together, the letters and numbers represent the half-month of the observation and its sequential order among all the asteroids discovered in that half-month. For example, in the designation 2007 BA_1, the letter B indicates the asteroid was

AMATEURS Charles W. Juels and Paulo Holvorcem tracked an asteroid on the night of October 28/29, 2002. The multiple observations (in yellow circles) enabled the Minor Planet Center to designate this near-Earth asteroid 2002 UQ_3. PAULO HOLVORCEM/CHARLES W. JUELS

observed in the half-month January 16–31, 2007. The letter A would normally indicate this was the first sighting of the half-month, but the addition of the subscript number 1 means it was the 26th. One cycle of the alphabet allows you to designate only 25 different asteroids in each half-month. (The letter I is excluded.) The additional subscripted number in the designation allows you to cycle through the alphabet an unlimited number of times.

After gathering several years' worth of observations of a new asteroid or dwarf planet, astronomers replace the provisional designation with a permanent sequential number. Finally, the discoverer of the asteroid can propose a name to the IAU. To date, 13,722 minor planets have names.

Too much of a good thing

By the 1930s, use of more-sensitive photographic plates had substantially increased asteroid observations. This overtaxed the handful of astronomers available to determine orbits armed only with mechanical calculators. By 1945, one numbered minor planet out of eight had gone missing because of shaky identifications. We could predict the positions of, at most, a few hundred objects per year with moderate reliability.

In 1947, the IAU founded the first Minor Planet Center at the Cincinnati Observatory to improve the handling of asteroid observations. Observatory Director Paul Herget served as the first head of the MPC. Herget and a single assistant scrounged time on electronic computers owned by companies in Cincinnati to calculate the gravitational effects of the planets on hundreds of asteroids. Astronomers elsewhere then used mechanical calculators to fit Herget's results to observations on record for the asteroids.

Thanks to an arrangement with Indiana University, in 1948 the MPC moved one of its telescopes to a site some 25 miles (40 km) from the university's Bloomington campus. Students and staff relocated lost asteroids and improved the quality of asteroid observations generally. As the University of Cincinnati acquired its own IBM 650 computer and the MPC staff grew, the Center increasingly assumed responsibility for both calculating planetary effects on asteroids and matching the calculated orbits to observations.

By the late 1950s, the ability to calculate orbits had improved enough to allow the MPC to put more effort into numbering new asteroids. By the mid-1960s, the Indiana program had achieved what it could with a 10-inch telescope. Thereafter, astronomers at the Crimean Astrophysical Observatory in the former Soviet Union became the world's leading asteroid-hunters. By 1978, when Herget retired and his observatory closed, the quality of orbit calculations had improved dramatically. The latest numbered object was 2060 Chiron, fewer than two dozen numbered minor planets remained lost, and the orbital calculations for every asteroid numbered since World War II were in good shape.

Moving day

In 1978, the IAU invited me to become director of the MPC and oversee its move to the Smithsonian Astrophysical Observatory. From Cincinnati I received a nine-track magnetic tape with some 200,000 minor-planet observations and a set of punched cards showing the last provisional designation used in each half-month — and Conrad Bardwell, principal assistant at the MPC since 1958.

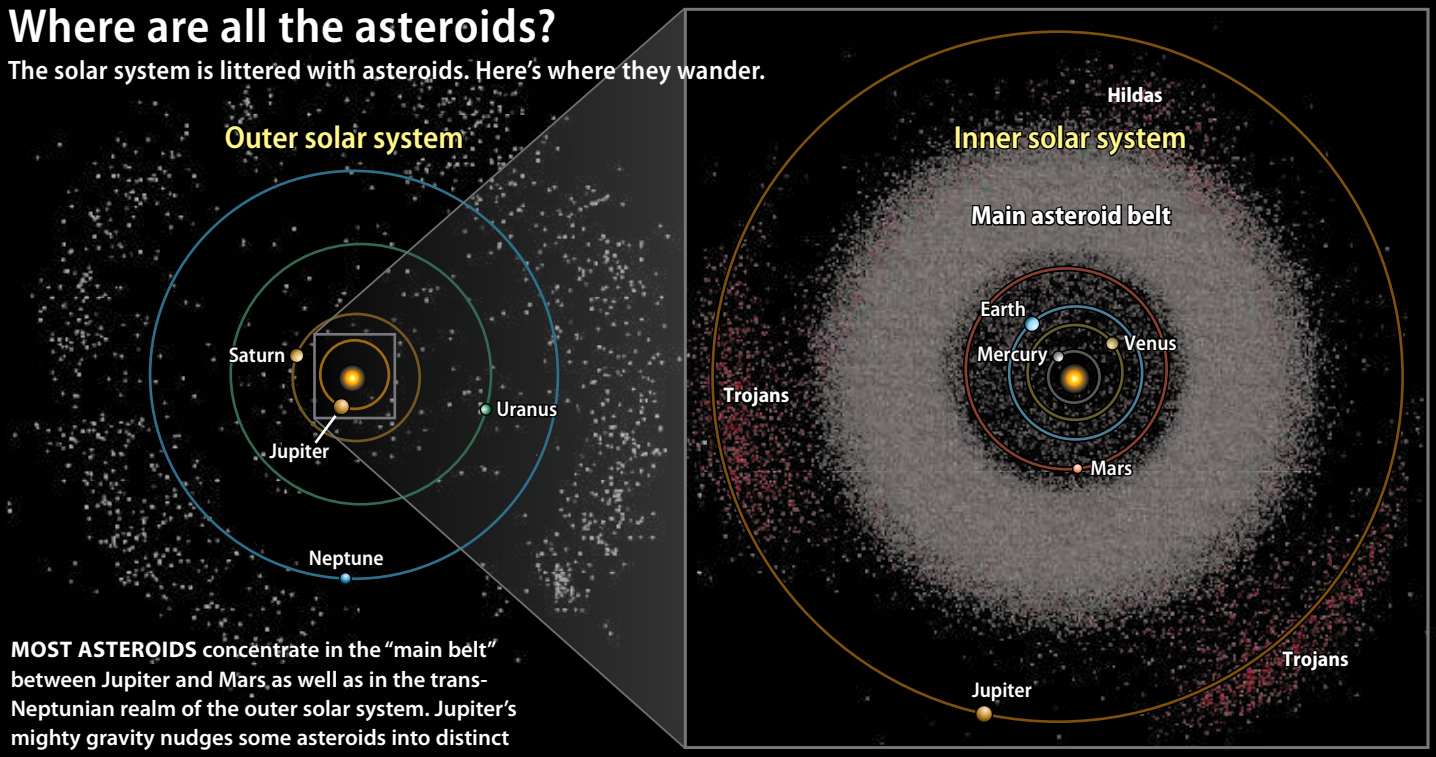
One change I made was to issue *Minor Planet Circulars* with observations, orbits, and associated material each month, rather than once every 6 to 8 months, as was the former practice. More frequent publication inspired observers to greater effort, which boosted the rate at which we could number minor planets and even further reduced the number of lost minor planets. By the time Bardwell retired in 1989, the total number of asteroid and comet

CRAIG NIEMI/CINCINNATI OBSERVATORY CENTER

MINOR PLANET CENTER Director Paul Herget (left), here talking to a colleague, used the early IBM 650 electronic calculator (far left) to calculate asteroid orbits in the late 1950s.

HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

THE MPC moved in 1978 to its present quarters in Cambridge, Massachusetts, with Brian Marsden as director. Computing improvements vastly increased asteroid discoveries.


Where are all the asteroids?
The solar system is littered with asteroids. Here's where they wander.
Outer solar system
Saturn
Uranus
Jupiter
Neptune
Hildas
Inner solar system
Main asteroid belt
Earth
Venus
Mercury
Mars
Trojans
Trojans
Jupiter
MOST ASTEROIDS concentrate in the "main belt" between Jupiter and Mars as well as in the trans-Neptunian realm of the outer solar system. Jupiter's mighty gravity nudges some asteroids into distinct groups such as the Trojans and Hildas.
ASTRONOMY: ROEN KELLY. SOURCE: MINOR PLANET CENTER/HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

observations in our files had increased to almost 550,000. In addition, the catalog of numbered minor planets had doubled to 4,295. Of all the numbered objects, only asteroids 719 Albert and 878 Mildred remained lost.

Gareth Williams succeeded Bardwell as the MPC associate director. He quickly introduced more automation to improve our computational capabilities. Although the CCD era was already well under way, electronic imaging did not eclipse film until the mid-1990s. By that time, several objects besides Pluto had been found beyond Neptune's orbit, and major efforts started up to locate comets and asteroids whose orbits crossed Earth's and, therefore, represented a potential hazard. In order to accommodate the flood of new discoveries of near-Earth objects, or NEOs, the MPC in 1993 started to issue *Minor Planet Electronic Circulars.*

In 1996, the MPC introduced the Near-Earth Object Confirmation Page (NEOCP) on the Web. Every time an observer suspects he or she has found a new NEO, the MPC posts its brightness and predicted positions for the next 24 hours — often within minutes of receiving the observations. This spurs many amateur and professional astronomers to undertake the follow-up observations the MPC needs to determine the NEO's orbit. Within 24 to 36 hours, an orbit is usually firm enough for us to remove the object from the NEOCP and issue a formal electronic circular with all the relevant information. This process, which depends on the contributions of observers in a dozen or more countries, gives NASA hope of fulfilling its instruction from Congress to find 90 percent of NEOs 1 kilometer or larger by the end of 2008.

By 2000, Williams had relocated both 878 Mildred and 719 Albert, lost since 1911 and 1916, respectively. With this, the MPC had finally accounted for all numbered asteroids. It continues to enlarge the catalog at a fast pace. In 2006 alone, we added 25,268 numbered asteroids.

Eyes on the prize

Identifying NEOs that could smash into Earth is important. But for amateur observers like Charles Juels, the honor of discovering and naming a celestial body for all time holds a particular fascination. And in 1999, Juels did eventually receive the ultimate reward for his dedication to asteroid-hunting.

On February 13, he sent us observations of two asteroids, one of which turned out to be previously undiscovered. The MPC gave it the provisional designation 1999 CA_3, meaning "the 76th minor planet found in the period February 1–15, 1999." Juels continued to observe 1999 CA_3, gathering additional data for calculating the asteroid's orbit, as the MPC machinery went into overdrive.

On the evening of February 21, our computers e-mailed a *Minor Planet Electronic Circular* announcing that Williams had identified 1999 CA_3 with two previously designated asteroids, 1982 EL_2 and 1997 SF_{34}. Entirely by coincidence, the circular went out to subscribers just 4 minutes after Juels completed his third CCD image of 1999 CA_3 that evening.

By October 2001, we had determined the orbit of 1999 CA_3 well enough to give it the sequential designation 29750. In 2003, Juels named it 29750 Chleborad, in honor of Californian amateur astronomer Cary Chleborad.

Juels has alone, or with observing partner Paulo Holvorcem, discovered 447 numbered minor planets — among them the potentially hazardous near-Earth asteroid 2002 UQ_3 (now known as the numbered minor planet 154,302). Juels' remarkable success exemplifies the fact that asteroid-hunting remains one of the few ways that amateurs can make important contributions to astronomy — and maybe even save the world!

ONLINE EXTRA See better views of the asteroids shown on page 41 and animated asteroid maps at www.astronomy.com/toc.

BY MARTIN RATCLIFFE AND ALISTER LING

JULY 07

Watch planetary fireworks light up summer nights

July opens in spectacular fashion with an evening display of Venus and Saturn in the same telescopic view. Bright Jupiter dominates the southern sky. And, through a telescope, Uranus, Neptune, Pluto, and even a new comet complete the month's evening sky show. ☾ **Venus** and **Saturn**, both located in Leo the Lion, make a stunning pair as darkness falls. Venus shines at magnitude –4.6; Saturn glows at magnitude 0.6. On July 1, from our perspective on Earth, the two worlds appear separated by only 47′. Astronomers call such a close pairing an appulse or conjunction; observers have about 2 hours after sunset to view this one. The two planets drift more than 1° apart a night later, and by July 7, nearly 4° separate the two worlds.

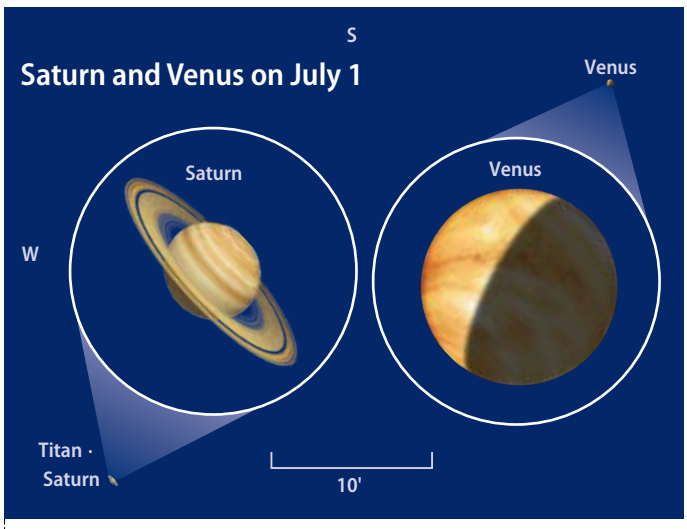
A lovely crescent Moon lies between Venus and Saturn July 16. All three objects, plus Leo's brightest star, Regulus, make a stunning view in binoculars.

Both Venus and Saturn appear at progressively lower altitudes at the same time each evening as the month progresses. An hour after sunset — *Continued on page 49*

VENUS MET SATURN July 15, 2001, among the stars of Taurus the Bull in the morning sky. This month, the planetary pair appears in Leo the Lion, low in the west as darkness falls. SID LEACH

44 See Saturn and Venus together
49 Jupiter's moons line up
49 Explore battered Heraclitus
50 When to view the planets
50 See a new comet
51 Follow 4 Vesta's turn in Scorpius
51 Glimpse Pluto in Sagittarius

Visible to the naked eye
Visible with binoculars
Visible with a telescope



SEE TWO PLANETS at once July 1. A wide-field view in a telescope can include both Venus and Saturn. Observers have about 2 hours after sunset to catch the pair. Can you locate Titan before Saturn sets? *ASTRONOMY:* ROEN KELLY

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

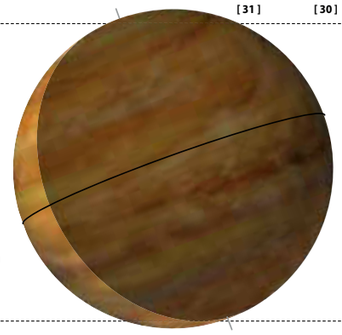
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

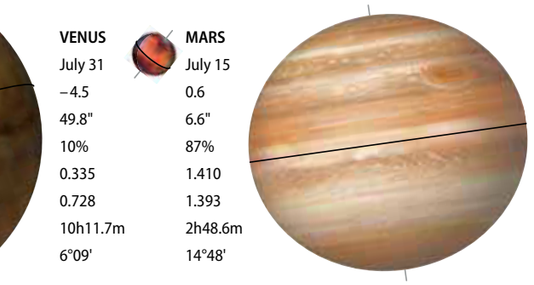
[16] [15] [14] [13] [12] [11] [10] [09] [08] [07] [06] [05] [04] [03] [02] [01]

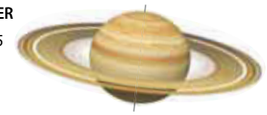
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

[31] [30] [29] [28] [27] [26] [25] [24] [23] [22] [21] [20] [19] [18] [17] [16] [15] [14]

PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	July 15	July 31	July 1	July 31	July 15	July 15	July 15	July 15	July 15	July 15
Magnitude	1.1	−0.9	−4.6	−4.5	0.6	−2.5	0.6	5.8	7.8	13.9
Angular size	9.1"	6.0"	31.3"	49.8"	6.6"	43.8"	16.5"	3.6"	2.3"	0.1"
Illumination	22%	72%	36%	10%	87%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.743	1.114	0.534	0.335	1.410	4.502	10.072	19.511	29.155	30.397
Distance (AU) from Sun	0.397	0.315	0.726	0.728	1.393	5.307	9.223	20.092	30.046	31.313
Right ascension (2000.0)	6h14.5m	7h31.6m	9h37.7m	10h11.7m	2h48.6m	16h36.5m	9h46.0m	23h18.6m	21h35.0m	17h47.1m
Declination (2000.0)	19°43'	21°44'	14°51'	6°09'	14°48'	−21°27'	14°47'	−5°19'	−14°40'	−16°26'

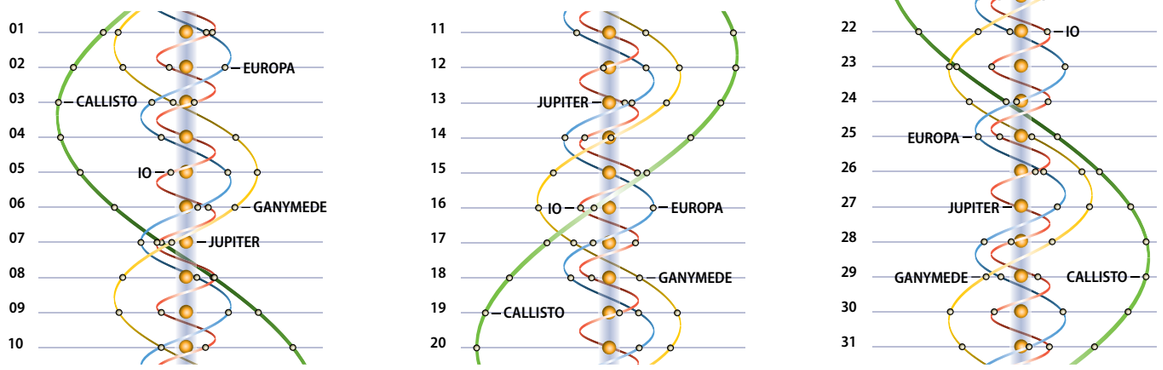


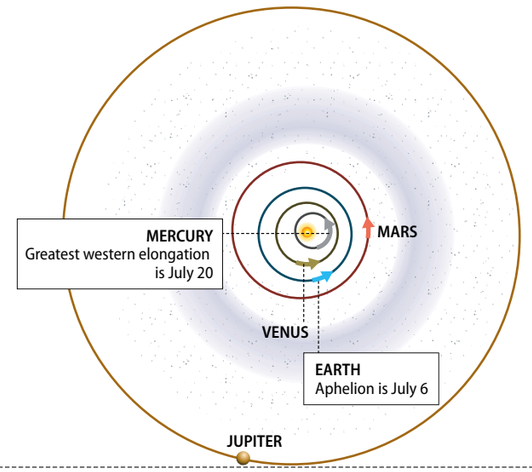




Jupiter's moons

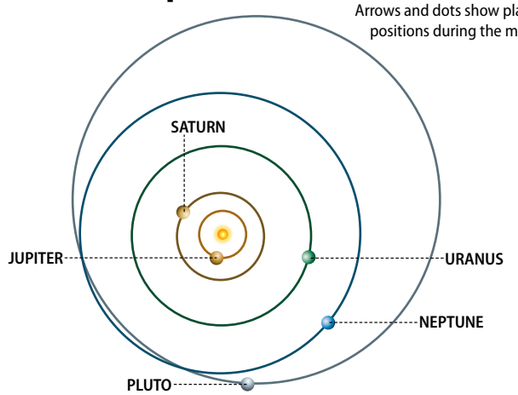
Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.





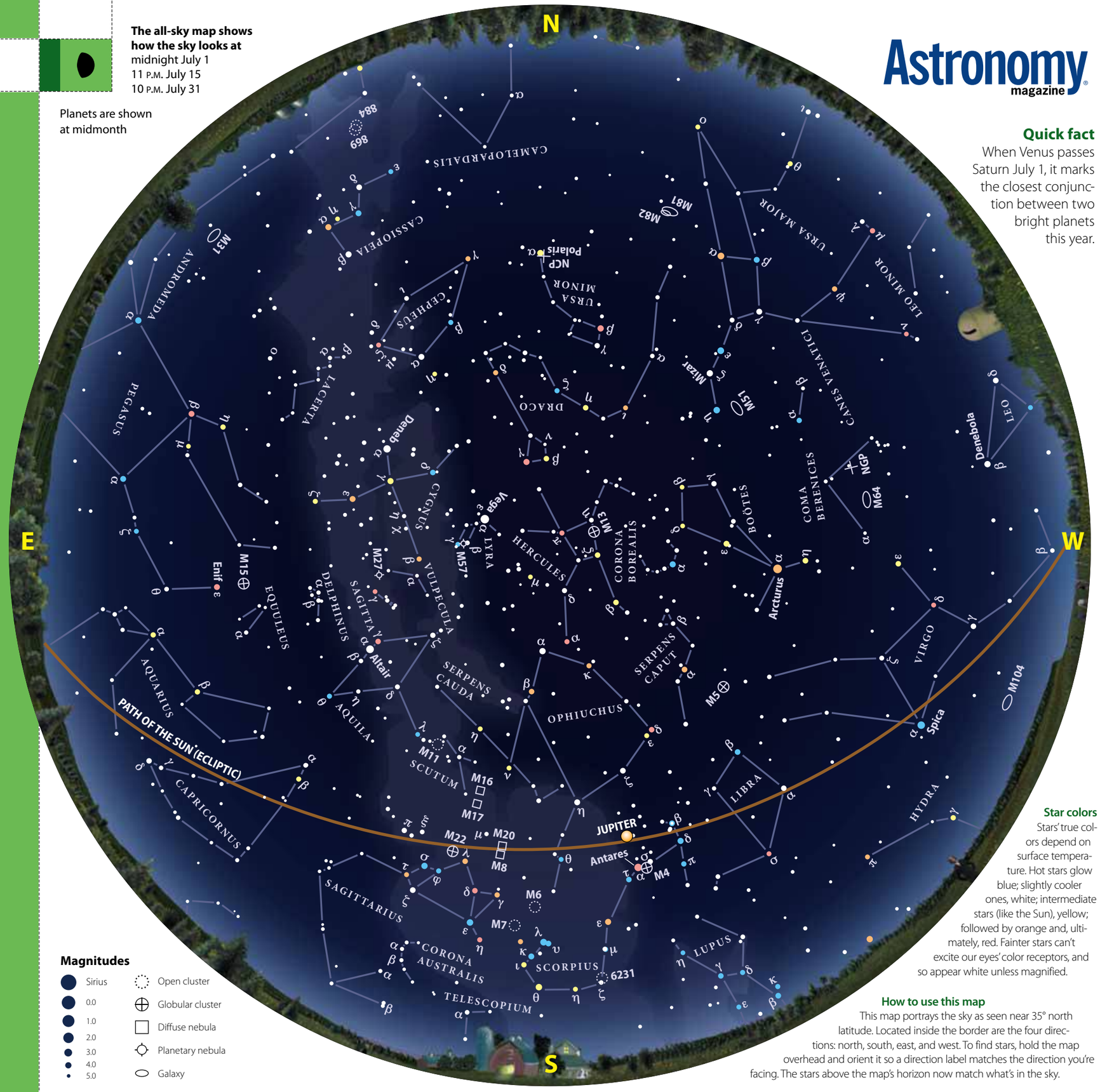
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

Quick fact
When Venus passes Saturn July 1, it marks the closest conjunction between two bright planets this year.

july 07

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
[01]	[02]	[03]	[04]	[05]	[06]	[07]
[08]	[09]	[10]	[11]	[12]	[13]	[14]
[15]	[16]	[17]	[18]	[19]	[20]	[21]
[22]	[23]	[24]	[25]	[26]	[27]	[28]
[29]	[30]	[31]				

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

01 Venus passes 0.8° south of Saturn, 9 P.M. EDT

05 The Moon passes 1.9° north of Uranus, 5 P.M. EDT

06 Earth is at aphelion (94.5 million miles from the Sun), 8 P.M. EDT

07 Last Quarter Moon occurs at 12:54 P.M. EDT

09 The Moon passes 6° north of Mars, 11 A.M. EDT

The Moon is at perigee (228,992 miles from Earth), 5:42 P.M. EDT

12 Venus is at greatest brilliancy (magnitude –4.7), 10 A.M. EDT

The Moon passes 9° north of Mercury, 11 P.M. EDT

14 New Moon occurs at 8:04 A.M. EDT

16 Venus passes 2° south of Regulus, 11 A.M. EDT

16 The Moon passes 0.04° south of Saturn, 7 P.M. EDT

17 The Moon passes 0.3° north of Regulus, 5 A.M. EDT

The Moon passes 3° north of Venus, 6 A.M. EDT

20 Mercury is at greatest western elongation (20°), 11 A.M. EDT

22 First Quarter Moon occurs at 2:29 A.M. EDT

The Moon is at apogee (251,127 miles from Earth), 4:43 A.M. EDT

25 The Moon passes 0.6° south of Antares, noon EDT

The Moon passes 6° south of Jupiter, 2 P.M. EDT

28 Southern Delta Aquarid meteor shower peaks

29 Full Moon occurs at 8:48 P.M. EDT

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary.

— *Continued from page 44*

July 1, Venus stands 15° high. But by July 31, it sets 40 minutes after the Sun. At month's end, Saturn lies 4° west of Regulus and 6° north of Venus.

Telescopic views of Venus reveal its diminishing crescent. Venus shrinks from 35-percent lit to 9 percent during the month, while the apparent size of the crescent increases dramatically from 32" to 51". Venus reaches its greatest brilliance — magnitude –4.7 — in mid-July.

Saturn, glowing fainter than Venus, is lost in twilight by month's end. The planet returns to the morning sky later in the year and performs another conjunction with Venus and the Moon in October.

By nightfall, **Jupiter** gleams low in the southern sky just 5° north-northeast of the bright red star Antares. Jupiter shines at magnitude –2.5, about 3.5 magnitudes brighter than Antares. Jupiter was at opposition last month; so it's now visible most of the night.

Look carefully and you'll notice that stars come in different colors. Antares is a cool, red-supergiant star with a surface temperature of 3,000° kelvins. Jupiter, of course, is a planet, visible by reflecting light from the Sun, which is twice as hot as Antares. The hotter temperature colors the Sun — and Jupiter — with a yellowish hue. Note the color difference between Jupiter and Antares.

Jupiter appears in the constellation Ophiuchus and lies about 381 million miles (613 million kilometers) from Earth.

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

Antares, Scorpius' brightest star, lies much farther away — 604 light-years. Their only connection is that they lie along a similar line of sight.

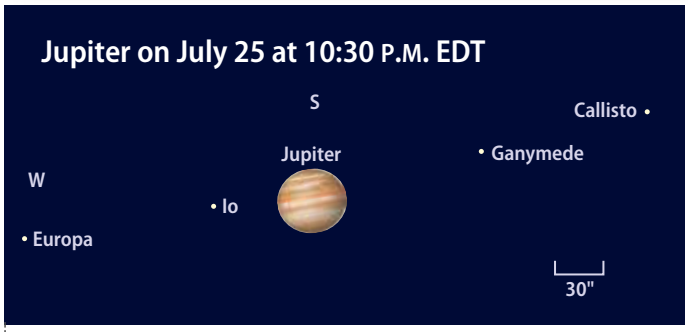
Jupiter reaches its highest altitude (30°) around 11 P.M. local daylight time in early July, and earlier in the evening by month's end. The low altitude affects telescopic views because Jupiter's light must travel through thicker air layers. Even so, Jupiter is an exciting target. Four bright moons are regularly on parade, while atmospheric details change by the hour (thanks to Jupiter's less-than-10-hour rotation period).

Your scope will reveal a 43"-wide disk split by two dark equatorial belts. The belts are obvious, but patient observing reveals other, subtler features. Our fluctuating atmosphere

MIDMONTH BRINGS A PERSEID PREVIEW

The run-up to August's Perseid meteor shower, one of the year's best and brightest, begins July 17. This month's late Full Moon bodes well for the shower, whose August 12 peak this year occurs the same day as New Moon.

But the Moon makes the Southern Delta Aquarids, July's most active shower, a wash-out. Normally, this shower's meteors can be seen from mid-July into August. So, bring on the Perseids!



ASTRONOMY: ROEN KELLY

LINED UP MOONS are a familiar sight for Jupiter fans. On July 25, see the innermost large moons (Io and Europa) on Jupiter's west side, while more distant Ganymede and Callisto hover to the east. Such alignments make Io's orbital motion perceptible.

EXPLORE BATTERED HERACLITUS

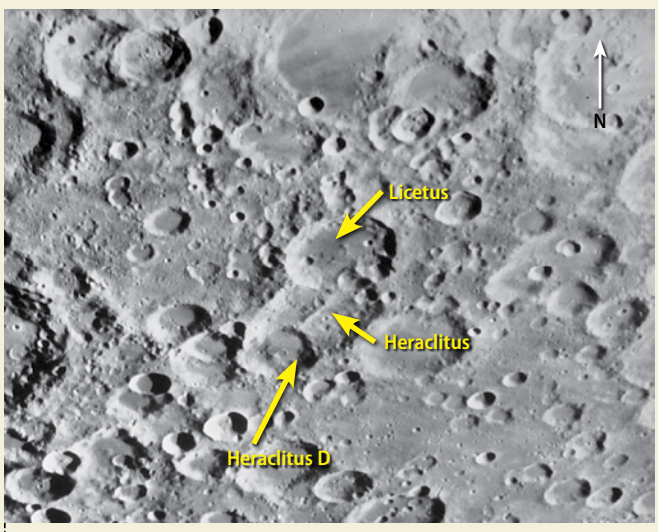
Located in the Moon's rugged southern highlands, the 56-mile-wide crater Heraclitus lies southeast of famous Tycho. Heraclitus shows a complex makeup thanks to dramatic changes after it formed.

Licetus, a slightly smaller crater, struck nearby and breached Heraclitus' northern rim. The crater's southern rim disappeared in a separate impact — the one that made Heraclitus D. Heraclitus shares its eastern wall with Cuvier.

What's odd about Heraclitus is the straight wall that runs almost north-south across its floor. This wall leads to a hill and a tiny crater where Licetus borders Heraclitus.

This is one of the southern highlands' most intriguing regions. Careful observation shows Heraclitus lacks its neighbors' depth. To see this, you'll need the right lighting conditions, which occur as the Sun rises (approaching First Quarter Moon) or sets (just before Last Quarter) over the region. The shadows make it clear Heraclitus D is the deeper of the two craters.

Heraclitus is named for a Greek philosopher who predates Socrates and Plato.



CONSOLIDATED LUNAR ATLAS (LPL/UA)

A STRAIGHT WALL RUNS almost north-south across the Moon's Heraclitus Crater. This feature connects Heraclitus D and Licetus, two newer craters that obliterated much of Heraclitus' rim.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (west)	Jupiter (southeast)	Mercury (east)
Jupiter (south)	Uranus (southeast)	Mars (southeast)
Saturn (west)		Uranus (southwest)

usually washes them out. But observe carefully, and you'll notice moments of extreme clarity. Enjoy these all-too-brief moments of calm air.

Jupiter's Great Red Spot, which has a salmon-pink hue, often is visible. Its new neighbor, Red Spot, Junior, is about ⅓ the size of the centuries-old spot. Red Spot, Junior, started off as a white oval but, to the surprise of planetary scientists, it changed color last year. They speculate the storm intensified and drove clouds to higher levels, where chemical reactions color the cloud tops.

If you observe at the same time every night, you see Jupiter exactly 2.4 rotations later. Cloud features visible on the planet's central meridian one night have rotated out of view on the following night.

Jupiter's big moons — Io, Europa, Ganymede, and Callisto — were first spotted by Galileo back in 1610. His observations revealed that not all celestial objects went around Earth. This ultimately led the way to the Sun-centered model of the solar system. And yet, your smallest scope far outpowers Galileo's.

Io skips around Jupiter in 1.8 days, and you'll notice the speedy moon's motion in a single night of observation. Sometimes it passes directly in front of Jupiter, and even casts a shadow onto the planet's disk. Watching these shadow transits, which occur many times a month, is fascinating. Each moon also passes behind Jupiter, which means it can be eclipsed. These moons have relatively large disks, so as they pass into shadow, they take a minute or so to fade out.

The other moons move slower than Io, and their periods reflect their distances from the giant planet. Europa orbits in 3.6 days, Ganymede about once a week, and Callisto every 16.8 days. Our pull-out maps show the changing positions of the four so-called Galilean moons each night.

This month offers an opportunity to track down the solar system's second-largest dwarf planet — **Pluto**. You'll need an 8-inch or larger telescope and dark, moonless skies to pull off this observation, though.

Pluto and its chilly brethren orbit the Sun in the inner portions of the Kuiper Belt, a vast reservoir of icy bodies left over from the solar system's formation. Eris, the largest known dwarf planet, lies beyond the view of most amateur scopes.

Pluto reached opposition last month, when the number of dark-sky hours reached a minimum. In late July, as the nights perceptibly lengthen, it's a good time to hunt for Pluto. It resides in extreme northwest Sagittarius. The dwarf planet lies due west of the Omega Nebula (M17), a favorite target of amateur astronomers.

Whenever you look at M17, remember to move your scope 8° west and try for Pluto. The open cluster M23 is also a helpful guide — Pluto is about 3.5° northwest of the group. Shining at magnitude 13.9, Pluto is an observing challenge. Arm yourself with a detailed star chart of the region. Once you think

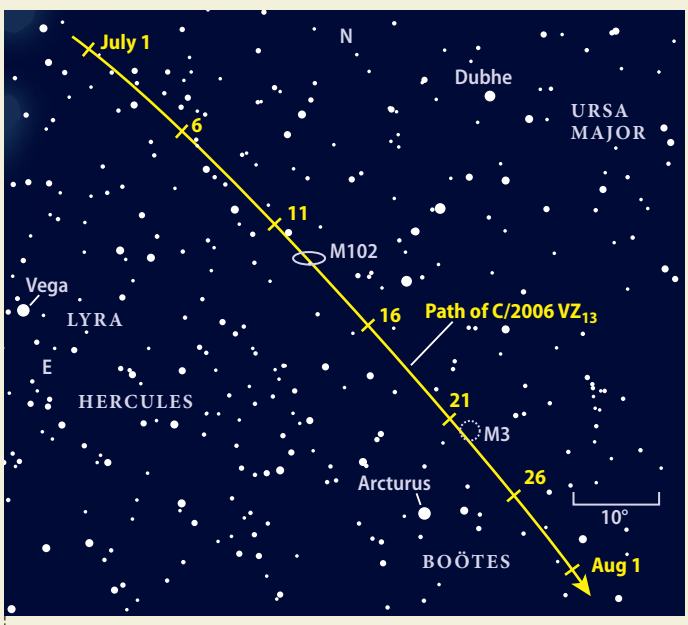
WATCH A NEW COMET CRUISE FROM DRACO THROUGH BOÖTES

Just in time for dark-sky summer stargazing, a new Comet LINEAR (C/2006 VZ_{13}) scoots clear across the northern sky. VZ_{13} slips along Draco the Dragon's spine, slides past Ursa Major, and slips between Boötes the Herdsman and his hunting dogs, Canes Venatici.

Glowing by reflected sunlight, the comet's coma and stubby dust tail should break the 10th-magnitude mark. This means that, in a dark sky, VZ_{13} will be an easy target to follow in a 4-inch scope.

On July 13, the elongated comet will be only 1° from the elongated lenticular galaxy M102 (NGC 5866). Although M102 is the same total magnitude as the comet, the galaxy's compact and well-defined lens shape gives it a higher surface brightness. Your eye will be drawn to it first, but take the time to study both objects at low and high power.

VZ_{13} gives us another nice treat on the 22nd when it passes 30' — the apparent size of the Moon — from M3, the sky's 12th-brightest globular star cluster. Light from the First Quarter Moon will subdue the comet's tail, but VZ_{13} remains high when the Moon sets just before midnight. It's a lovely photo opportunity, whether you're shooting with a telephoto lens or through a wide-field scope.



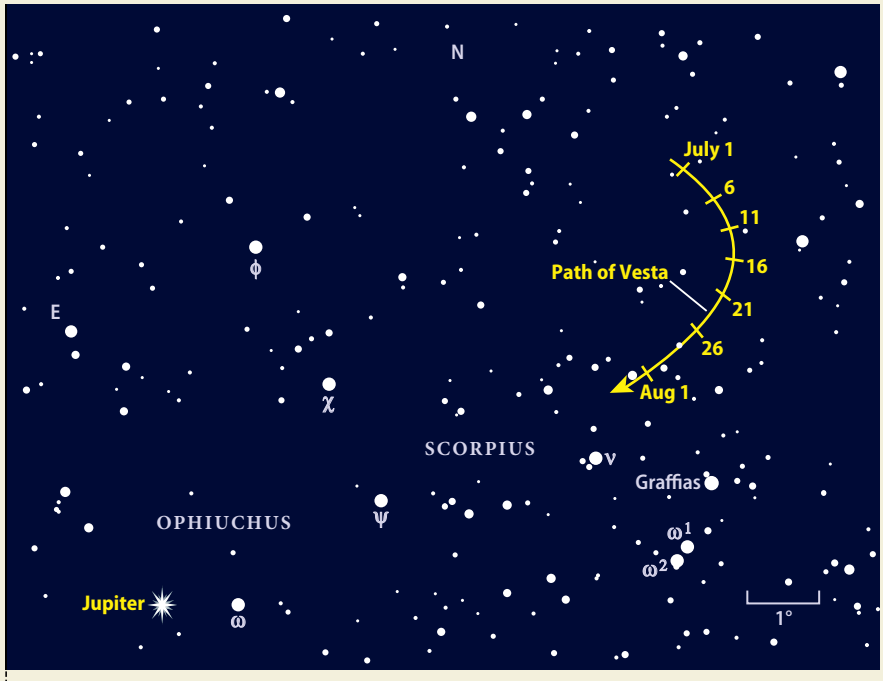
COMET LINEAR (C/2006 VZ_{13}) **sweeps through Draco, Boötes, and Canes Venatici in July.** *ASTRONOMY:* ROEN KELLY

VESTA FADES, BUT STILL GLEAMS IN BINOCULARS

From an apartment or suburban backyard, it's easy to find and follow 4 Vesta — the brightest asteroid — in binoculars, if you have a good view of the southern sky.

Start at Jupiter, the bright beacon low in the south once the sky gets dark. Below the giant planet lies the twinkling, ruddy, red-supergiant star Antares. At Jupiter's right is an angled line of three equally spaced, blue-white stars — Phi (ϕ), Chi (χ), and Psi (ψ) Ophiuchi. Star-hop south along this line to where the next star in the line ought to be. This places your binocular view in the middle of Vesta's July travels.

At magnitude 6.1, Vesta is the brightest object to the east (left) of 49 and Theta (θ) Ophiuchi. As Earth pulls ahead of Vesta through July, the asteroid gradually fades to 6.7. Check its position every 3 or 4 nights. During this time, the 300-mile (500 km) wide, slightly egg-shaped boulder will shift noticeably relative to the brighter stars in your binoculars' field of view.

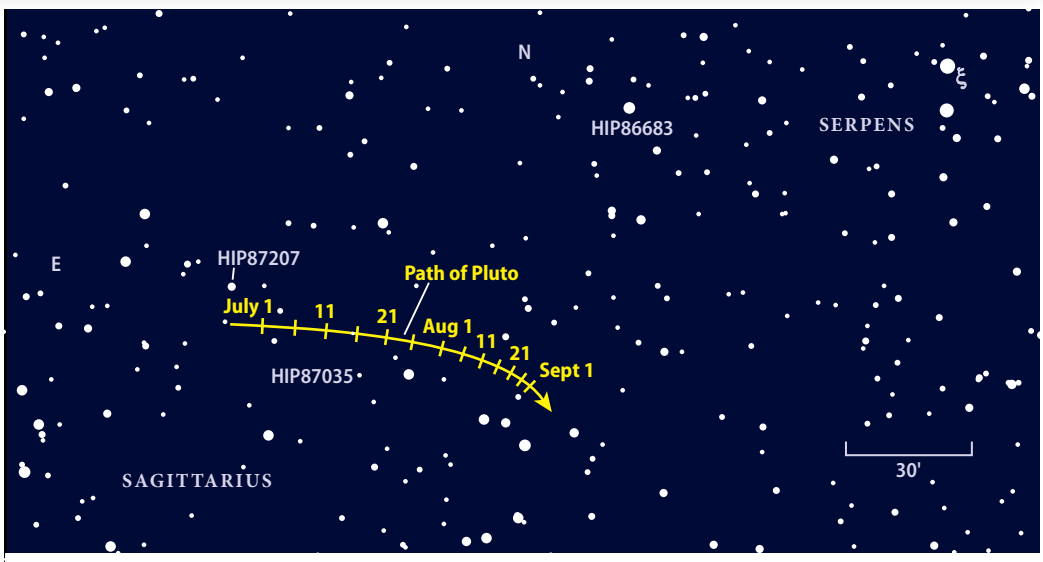


VESTA SLIPS BEHIND Earth throughout July. As its distance from us grows, the asteroid fades from naked-eye brightness. Jupiter is shown at midmonth. *ASTRONOMY*: ROEN KELLY

you've found Pluto, be sure to check for its motion on subsequent nights.

Neptune is an easier target. The giant planet is rising in the southeast as Jupiter crosses to the sky's western half. Wait until after midnight for better views of the planet, located in Capricornus. You'll find it about 2.3° north of Gamma (γ) Capricorni. You can spot it with binoculars as it treks westward from night to night, shining at magnitude 7.9. An easy way to find Neptune is to look for the line of three magnitude 5 stars — 45, 44, and 42 Capricorni — above Gamma. To their right is a line of magnitude 7 stars, the faintest of which is Neptune.

Shining at magnitude 5.8, **Uranus** is an easy target in binoculars or a small telescope. It lies on Aquarius' eastern side between 4.2-magnitude Phi (ϕ) Aquarii and 5.6-magnitude 96 Aquarii. The gap between Uranus and 96 Aquarii widens each night. By July 31, Uranus is 0.9° northeast of Phi.



PLUTO COASTS between open cluster M23 and Xi (ξ) Serpentis. To be sure you've observed the dwarf planet, check its changing position on subsequent nights. *ASTRONOMY*: ROEN KELLY

Mars brightens from magnitude 0.7 to 0.5 during July, as it slides across southern Aries and into Taurus. The planet lies 5° south of a waning crescent Moon July 9. By July 31, the Red Planet stands 7° southwest of M45, the famous Pleiades open star cluster.

Still displaying a tiny 7" disk, Mars lies more than 139 million miles (224 million km) away. The Red Planet will reach opposition in December.

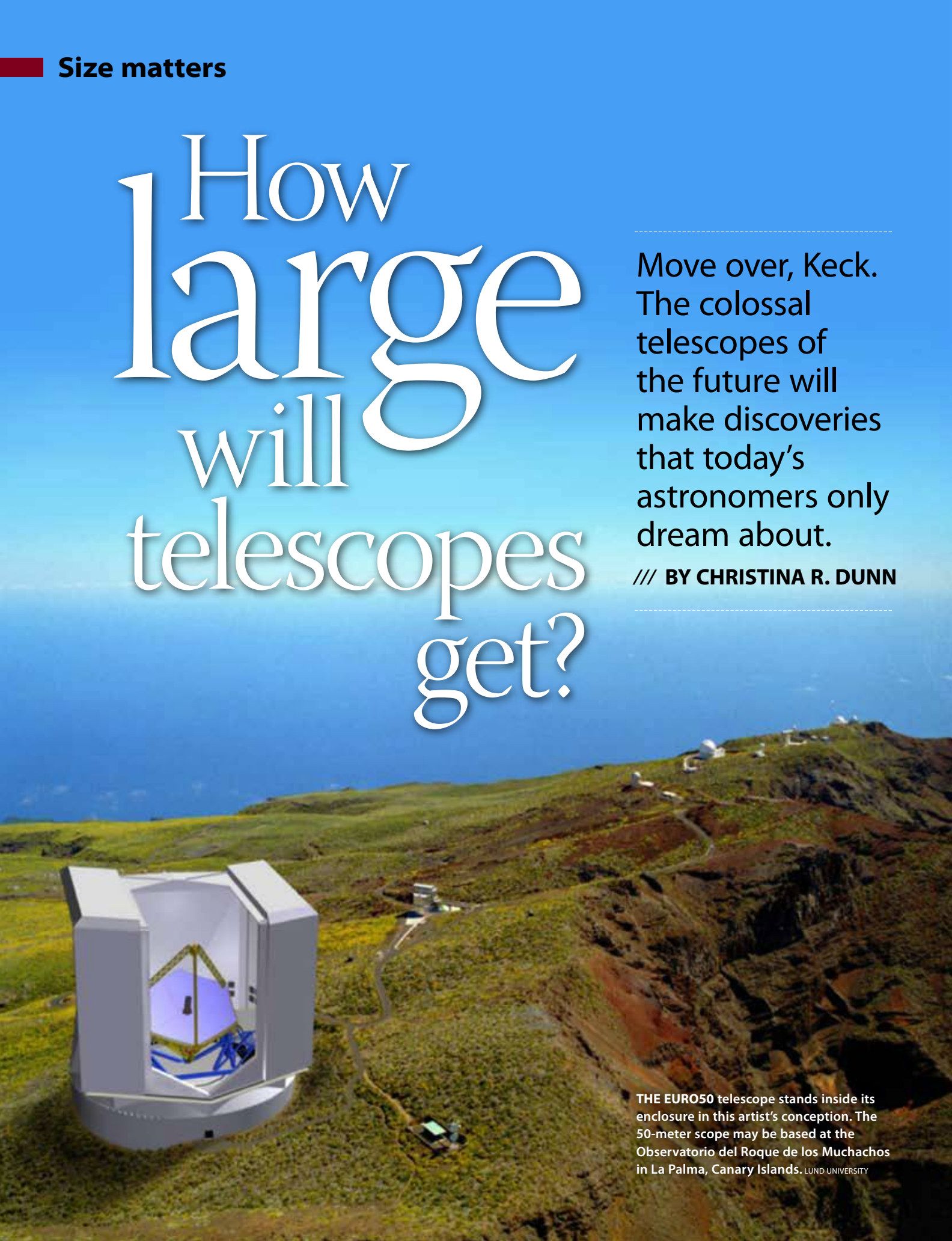
Mercury greets early risers in one of the year's best morning views of the innermost planet. It reaches its greatest elongation west of the Sun July 20, when it lies 20° from our star. Half an hour before sunrise July 18, as Mercury rises with Betelgeuse in the east, a telescope will show the magnitude 0.7 planet with a 32-percent-lit crescent. By July 25, Mercury is magnitude –0.3, lying in the middle of Gemini, and sporting a 53-percent phase. This fills out to 73-percent illuminated by month's end, when Mercury glows at magnitude –0.9 just 6.5° south of Pollux in Gemini.

Earth reaches its farthest point from the Sun (aphelion) July 6 at 8 P.M. EDT.

How large will telescopes get?

Move over, Keck. The colossal telescopes of the future will make discoveries that today's astronomers only dream about.

/// BY CHRISTINA R. DUNN



THE EURO50 telescope stands inside its enclosure in this artist's conception. The 50-meter scope may be based at the Observatorio del Roque de los Muchachos in La Palma, Canary Islands. LUND UNIVERSITY

A new class of astronomical telescopes is evolving in the minds of engineers and astronomers. The best word to describe these instruments is large — extremely large. The term "extremely large telescope," or ELT, refers to optical telescopes with primary mirrors 98 feet (30 meters) or more in diameter.

Extremely large telescopes, with primary mirrors between 98 and 328 feet (30 to 100 meters) across, will dwarf the Keck telescopes atop Mauna Kea in Hawaii — currently the world's largest, at 10m apiece. These mirrors' collecting areas will range from 9,682 to 107,639 square feet (900 to 10,000 square meters). Their sizes will dwarf the infield of a baseball diamond, which covers 8,100 square feet (753 square meters), and some will surpass a 47,700-square-foot football field.

The Thirty-Meter Telescope (TMT), Euro50, the Giant Magellan Telescope (GMT), and the OverWhelmingly Large (OWL) Telescope are four such proposed projects. American and Canadian astronomers, including groups at Caltech, the University of California, and the University of Victoria, are joining forces to construct the TMT, scheduled to be operational in 2015. Possibilities for the TMT's location include Mauna Kea, northern Chile, and northern Mexico. As its name suggests, the TMT will be 98 feet (30m) across, which is roughly half the wingspan of a Boeing 747 jet.

Euro50, envisioned to be 164 feet (50m) in diameter, is a collaboration of institutions in Sweden, Spain, Ireland, Finland, and the United Kingdom. Location possibilities for the Euro50 include northern Chile and the Canary Islands. Planners anticipate the Euro50 will be completed in 2013.

The Giant Magellan Telescope will have the resolving power of an 80-foot (24.5m) primary mirror. The GMT is a collaboration among universities and research institutions in the United States. Scheduled to be in operation by 2016, this extremely large telescope will peer beyond the Milky Way to study the universe's expansion, the births of stars, and the mysteries of black holes.

The OWL project, at 328 feet (100m), is the largest optical telescope in the works. OWL is the brainchild of the European Southern Observatory (ESO). The OWL group also is considering Chile and the Canary Islands. Planners expect the 197-foot (60m) OWL to start observations in 2016, with the central portion of the mirror in place. They anticipate completing the remainder of OWL's mirror by 2021.

Christina R. Dunn *is an astronomer at University College London and a guest researcher at Lawrence University in Appleton, Wisconsin.*

Bigger is better

Why the drive to build giant telescopes? Effective telescope design has two important goals: to maximize light-gathering power and to improve resolution.

Modern telescopes use large curved mirrors to collect light. An optical telescope's primary mirror reflects the photons that strike it to a smaller secondary mirror, which directs them into a camera or other scientific device. A telescope's light-gathering power is the number of photons it can capture. The simplest way to increase light-gathering power is to build a larger telescope mirror — more area increases the number of photons that strike the telescope's mirror. The more photons a telescope collects, the fainter objects it can study.

KECK'S TWIN TELESCOPES, currently the world's largest optical and infrared telescopes, stand atop Mauna Kea volcano in Hawaii. These instruments probe the origin, structure, and ultimate fate of the cosmos. UNIVERSITY OF HAWAII/IFA

Increasing the size of a telescope's primary mirror also increases its resolving power. Resolution is a measure of how finely detailed an image is, and this directly relates to the amount of light a telescope collects. The most straightforward way to improve a telescope's performance is to increase the size of the main mirror. The Keck telescopes served as a "proving ground" for many of the advances in astronomical technology that will make the era of extremely large telescopes possible.

Mirrors come in different shapes

The Keck telescopes' 33-foot-diameter (10m) main mirrors are made of 36 hexagonal segments, each 5.9 feet (1.8m) across. A segmented mirror is lighter than a single mirror would be. This saves money in the construction of support structures.

A conventional solid telescope mirror is extremely heavy. The main mirror of the Hale 200-inch (5m) telescope on Palomar Mountain, California, weighs 40 tons — about the same as Kecks' 36 mirror segments combined, even though it has only about one-quarter of the surface area. The mirror's mass is necessary for it to remain rigid and hold its shape, no matter the angle of the telescope. If the mirror were too thin, it would slump as it tilted and lose its shape, resulting in blurry images.

The main mirror of an extremely large telescope will be made of an array of segments. To create a mirror of ELT proportions requires far more segments than Kecks'.

Euro50's plans call for 618 segments, while OWL will have more than 3,000. Each segment of the OWL and Euro50 telescopes will be about 6.5 feet (2m) wide. Having an array of mirrors, rather than a single piece of glass, introduces a new problem: Each hexagon must be perfectly aligned with each of its neighbors in order to form a perfect image. Active-optics technology addresses this issue. A system of actuators adjusts each mirror segment's position several times a second by subtly pushing and pulling on the mirror. The active-optics system constantly monitors the shape of the entire segmented mirror and brings the segments into alignment.

What shape should those segments form? The primary mirror must be curved in order to focus light. That curvature can be spherical or parabolic. If the primary is spherical, each of its mirror segments can be identical, because a spherical mirror has the same amount of curvature everywhere.

A spherical mirror, however, cannot produce a perfect focus. The image formed will have an optical defect called spherical aberration that designers can fix by adding a correcting element to the telescope. The OWL Telescope is designed with a spherical mirror, meaning that each of its 3,014 mirror segments will be exactly the same, simplifying the manufacturing process.

A parabolic mirror eliminates the problem of spherical aberration because a parabola will form a perfect focus. The

THE THIRTY METER TELESCOPE'S giant mirror will comprise more than 700 segments. An adaptive-optics system will help compensate for Earth's turbulent atmosphere. TMT PROJECT

parabolic mirror is more steeply curved in the center than at the edges. This means the hundreds of hexagonal pieces comprising the mirror can no longer be identical — they must be fabricated with varying amounts of curvature, depending on their positions within the mirror. Euro50 is an example of an ELT design with a parabolic primary mirror.

Sixty meters seems to be the critical point in the spherical-versus-parabolic decision. For a mirror wider than 197 feet (60m), it is more cost effective to make all the segments identical and add corrective optics to fix the spherical aberration. For mirrors smaller than 197 feet, it is less expensive to form a parabolic mirror than to correct spherical aberration.

Why invest billions of dollars in extremely large telescopes when those resources could be used for space telescopes? In terms of light-gathering power, a ground-based telescope is much less expensive. For the same budget, a ground-based telescope can be built many times larger than its orbiting counterpart.

The advantage falls to the space telescope, however, when considering resolution. While a 164-foot (50m) telescope gathers more light than a 26-foot (8m) one, the image resolution will be about the same for both because Earth's atmosphere limits the larger one's resolution. Adding an adaptive-optics system compensates for this situation. With adaptive optics, an earthbound telescope can almost match a similarly sized space telescope's performance.

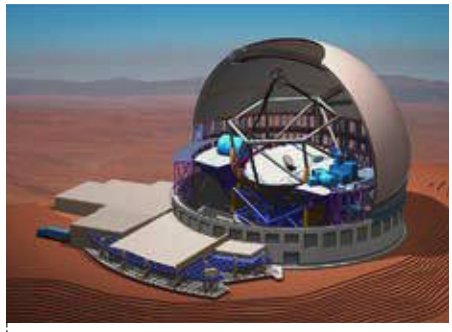
An adaptive-optics system analyzes the incoming image of a guide star to see how blurry it is. A flexible mirror then corrects the shape of the incoming light waves to bring the star into focus.

An adaptive-optics system uses a comparison point source, like a bright star, to analyze the atmosphere. A telescope's field of view is small, however, and there may not be a suitable bright star within the field for every observation. Instead, a laser can be used to excite sodium atoms in the upper atmosphere. As meteors travel through Earth's atmosphere, they release sodium. The excited sodium atoms produce an artificial star the adaptive-optics system can use as a guide. Adaptive optics are already in use on several telescopes atop Mauna Kea.

Big telescopes, big science

The payoff for extremely large telescopes is ground-breaking science. The unprecedented light-gathering power and resolution of ELTs will show us the universe with a level of detail never before possible. Observations from ELTs will span from our own solar system to the most distant galaxies.

Extremely large telescopes will capture views of planets orbiting the Sun comparable to those produced by fly-by space probes like the Voyager spacecraft, but without the tremendous expense and years of planning required for space missions. Regular monitoring of phenomena such as changes in Mars' polar ice caps or volcanic eruptions on Jupiter's moon Io will be possible.



TMT PROJECT

THE TMT is in the preliminary design phase. Project planners envision a facility such as the one shown here for this extremely large telescope.

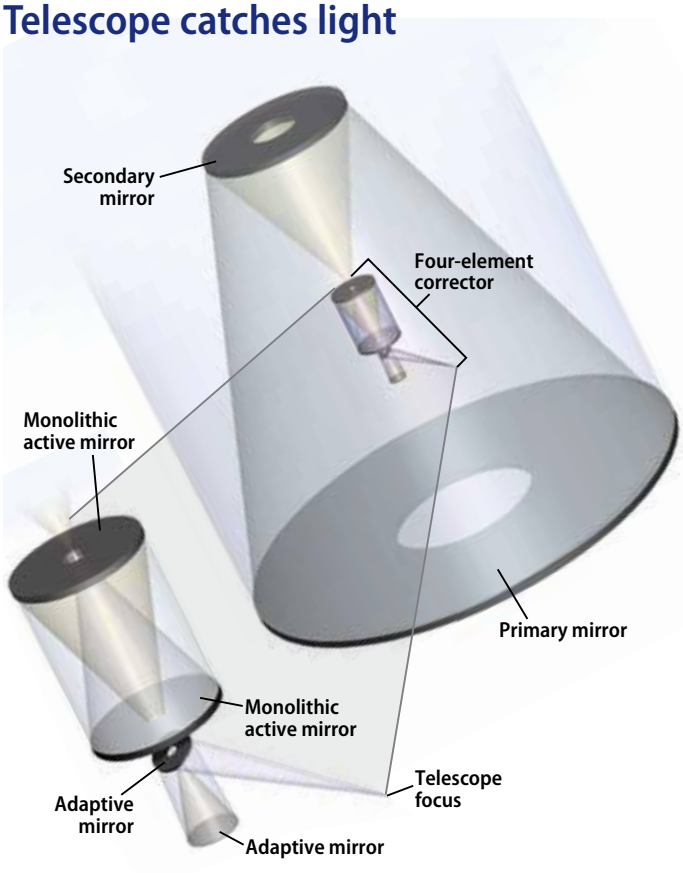
ELTs will address the challenges of searching for planets around other stars. Astronomers currently detect such extrasolar planetary systems by observing the wobble in a distant star's position due to the gravitational pull of a planet on its host star. The size of the star's wobble indicates the planet's mass. A drawback to this method is that it does not allow us to see what the planet looks like or to determine the nature of its atmosphere. The resolution produced by extremely large telescopes opens the possibility of imaging extrasolar planets. We will then be able to perform spectroscopic studies of them and also look for biological markers.

Surveys of thousands of stars to look for earthlike planets also could tell us how common habitable planets are, as well as what types of stars are most likely to have planets. Cataloging the types of planets found around a variety of stars will clarify the relationship between a star's characteristics and the types of planets accompanying it. ELT observations also will capture planetary systems at different ages. With this information,

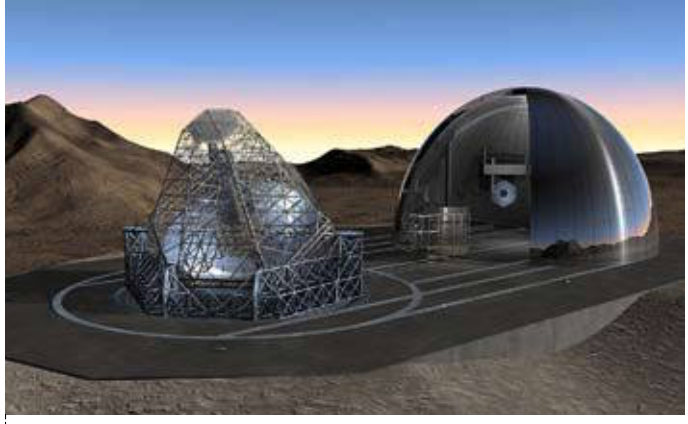
LUND UNIVERSITY

A SIZE COMPARISON between the Euro50 and a Boeing 747 jet shows it's no contest: The 50-meter scope is nearly as wide as the 70-meter jet in this artist's rendering is long.

How the OverWhelmingly Large Telescope catches light

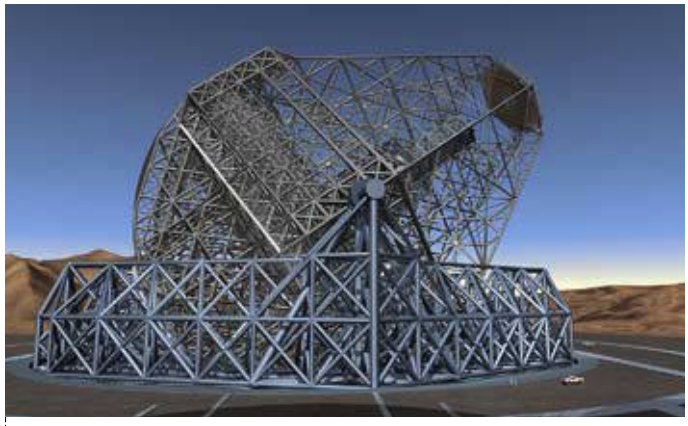


THE OWL'S OPTICAL DESIGN combines adaptive and active optics with a segmented mirror. This high-resolution scope will comprise a spherical primary mirror, a flat secondary mirror, and a four-element corrector. *ASTRONOMY*: ROEN KELLY, AFTER ESO



ESO

THE OVERWHELMINGLY LARGE (OWL) TELESCOPE'S primary mirror will span 100 meters and provide unrivalled light-gathering power. The scope will operate in open air, as shown in this artist's concept. During daylight, a retractable dome will cover the massive instrument and its retinue of image-enhancing electronics.



ESO

THE OWL TELESCOPE will be capable of resolving details down to a milliarcsecond. This giant scope will search for planets orbiting other suns and investigate the properties of dark matter, which dominates our universe.

astronomers can piece together a more complete picture of how solar systems form.

Scientists are interested not only in the histories of extrasolar planets, but they also want to learn more about the stars such planets orbit. When did the first generation of stars start to burn, and what caused them to form?

Astronomers can investigate galactic histories because light travels at a finite speed. We see the image of an object as it looked when it emitted the light. Light from distant objects must travel for a long time to reach Earth, so astronomers see that object as it looked in the past. Thus, detecting light from the first stars means we are looking at extremely distant stars.

To find one of these stars, astronomers will hunt for the moment in its life when it was its brightest — in the midst of a supernova explosion. Some supernovae can outshine an entire galaxy. Finding these first stars and studying their habitats will provide invaluable data about the early universe.

The search for the first stars also leads to the first galaxies. Why and when did these galaxies form? Galaxies were born from regions in the early universe that had a slightly higher density of matter than surrounding space.

One way to locate these cosmological seeds is to map the distribution of matter in the early universe. Unfortunately, much of the universe is filled with dark matter — mass that gives off no detectable radiation. So, more subtle methods must be used to study the universe's structure.

Dark matter gives its location away by the gravitational effect it has on matter, which emits light and can be mapped by observing the orbits of stars within galaxies. Extremely large telescopes will study the most distant and faint galaxies.

ELTs could allow astronomers to look for evidence supporting theories about the early universe. Many cosmological theories define space using 10 or more dimensions. If ELTs observe distant-enough objects, astronomers could look back in time far enough to see an epoch when physical constants deviated from their current values because of these extra dimensions.

Determining the value of these constants, such as the speed of light or the gravitational constant, would allow astrophysicists to experimentally test cosmological theories. Some of these theories include the possibility of multiple universes. The observations possible with ELTs may allow astronomers to determine if the early values of physical constants are compatible with these theories, thus placing the multiverse in or out of the realm of possibility.

Of all the possibilities being discussed for extremely large telescopes, the most certain is that they will expand our knowledge in completely unanticipated ways. Whatever cosmic discoveries await these behemoth telescopes, they are sure to be extremely large. A

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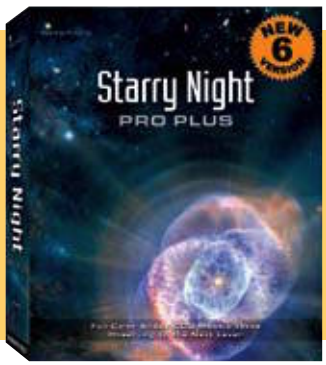


THIRD PRIZE - One Awarded

StarShoot Solar System Color Imager II

The StarShoot Solar System Color Imager II has four times greater resolution than most competing models – 1.3 megapixels to be exact – so you'll capture intricately resolved images that previously only the most skilled astrophotographers could achieve. It comes with *MaxIm DL Essentials Edition* software for efficient image capture, stacking, and processing. #52068

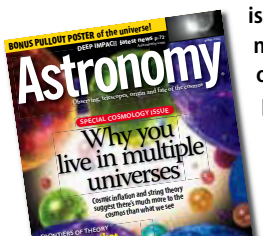
RETAIL VALUE $179.95

FOURTH PRIZE - 10 Awarded

A Year's Subscription to *Astronomy* magazine

Stay up-to-date with the hobby while learning about equipment and techniques for the beginning and more experienced stargazer. *Astronomy* is the world's most popular magazine for the astronomy-oriented public. 12 issues per year.

RETAIL VALUE $42.95



FIFTH PRIZE - 15 Awarded

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This must-have for all stargazers features 24 full-color maps that cover the entire sky. Also includes lists of the best objects to observe, 45,000 stars plotted down to magnitude 8.0, and 100+ dazzling photos.

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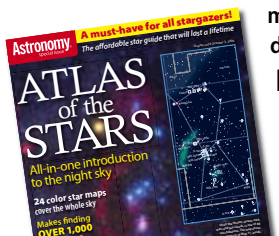
Astronomy
A must-have for all stargazers!
ATLAS of the STARS
All-in-one introduction to the night sky
24 color star maps cover the whole sky

Astronomy's Summer 2007 Sweepstakes Official Rules

1. No Purchase Necessary. Official entry forms are bound in the June 2007, July 2007, and August 2007 issues of Astronomy. The *Astronomy* 2007 Summer Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies and sponsoring companies are not eligible to participate.

2. Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with name, address, city, state or province, and zip or postal code to: The Astronomy 2007 Summer Sweepstakes, P.O. Box 1199, Waukesha, WI 53187-1199. Or enter online by filling in the Online Entry Form and hitting the SUBMIT ENTRY key. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for The Astronomy 2007 Summer Sweepstakes will be August 20, 2007, and all entries must be transmitted or postmarked no later than that date.

3. Prizes and Odds of Winning. One drawing will be held on or around October 19, 2007 for the following awards: One (1) Grand Prize consisting of a Sirius 120ED EQ-G GoTo Apo Refractor (retail value $3,099.95). One (1) First Prize consisting of a SkyQuest XT8 IntelliScope with Computerized Object Locator (retail value $619.95). One (1) Second Prize consisting of a *Starry Night Pro Plus 6.0* (retail value $249.95). One (1) Third Prize consisting of a StarShoot Solar System Color Imager II (retail value $179.95). Ten (10) Fourth Prizes each consisting of a one-year subscription to *Astronomy* magazine (retail value $42.95 each). Fifteen (15) Fifth Prizes each consisting of a copy of *Astronomy* magazine's special issue, Atlas of the Stars (retail value $12.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for Astronomy is 131,288. Sweepstakes void in Quebec and void where prohibited.

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Explore the brightest stellar birthplace in the summer Milky Way.

/// BY RAYMOND SHUBINSKI

All about the Lagoon Nebula

And now for tonight's weather report.

In the Lagoon Nebula (M8), expect winds up to 450,000 mph. These blasts will be accompanied by frigid temperatures hovering around –440° F (10 Kelvin). Look out for violent twisters that will produce intense wind shear in the area around the Hourglass Nebula. Elsewhere in the Lagoon, the night should be beautiful with the stars of open cluster NGC 6530 shining brightly.

Although fanciful, such a "space-weather" forecast accurately portrays conditions in one of the sky's most beautiful and accessible star-forming regions. And the Lagoon's observational history makes an equally fascinating story with its science.

Locating the Lagoon

During July's hot nights in the Northern Hemisphere, two zodiacal constellations — Scorpius and Sagittarius — ride low in the south. Scorpius the Scorpion, with Antares, its flaming-red supergiant star, looks a lot like its namesake. Scorpius almost appears to scuttle along the horizon with uplifted tail ready to strike.

Following in close pursuit is Sagittarius the Archer, which is tough to identify as the mythical beast known as a centaur — a half-man, half-horse figure. Sagittarius ranks 15th in size among the 88 constellations. In fact, Sagittarius is 75 percent larger than the stretched-out scorpion he pursues. This centaur has an arrow ready to loose on the heart of the deadly scorpion.

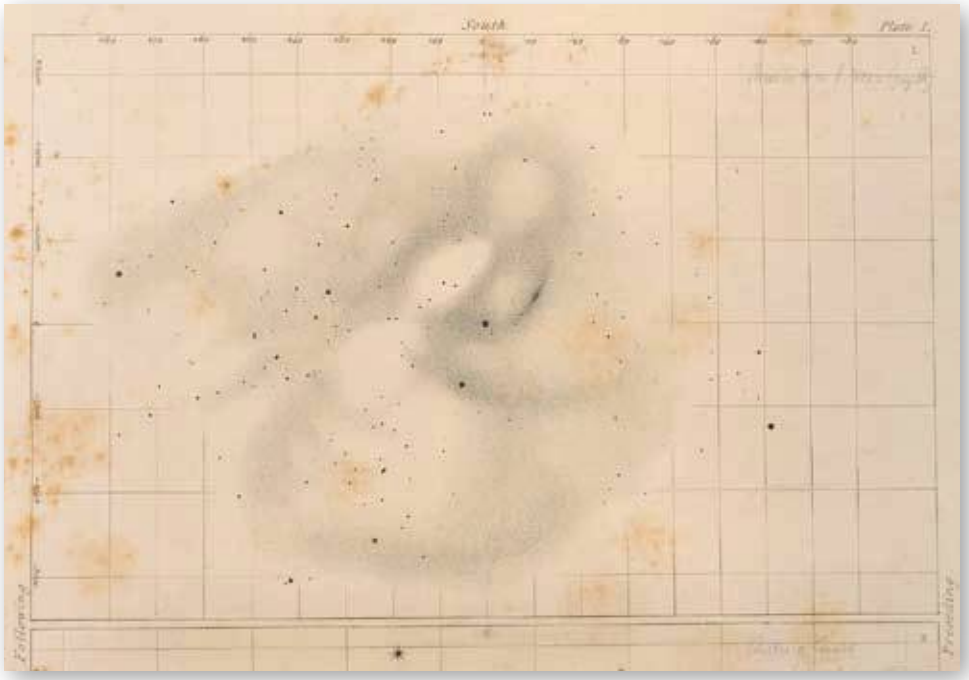
Tracing Sagittarius' outline is difficult, so observers look for the asterism of the "teapot." The spout of the teapot is marked by the stars Delta (δ), Gamma (γ), and Epsilon (ε) Sagittarii. Delta and Epsilon, along with Zeta (ζ) and Phi (ϕ), mark the "pot." The "handle" comprises Tau (τ), Sigma (σ), Zeta, and Phi. Finally, the "lid" combines Lambda (λ) with Phi and Delta.

If the sky is dark, once you find the spout you'll see the "steam" of the Milky Way — the tea is ready — rising from the horizon and cutting across the velvety summer sky. A number of fuzzy objects you can just glimpse with your unaided eyes appear as puffs within the steam.

French comet-hunter Charles Messier (1730–1817) cataloged several of these objects in the mid-18th century. In fact, Sagittarius contains more Messier objects than any other constellation — 15. The two above the teapot's spout are the Trifid Nebula (M20) and the Lagoon Nebula, and talk about a tempest!

FAST FACTS ABOUT M8

Object type: Emission nebula
Other names: Lagoon Nebula, NGC 6523
Constellation: Sagittarius
Right ascension: 18h04m
Declination: –24°23'
Size: 75'
Magnitude: 6.0
Approximate distance: 5,200 light-years



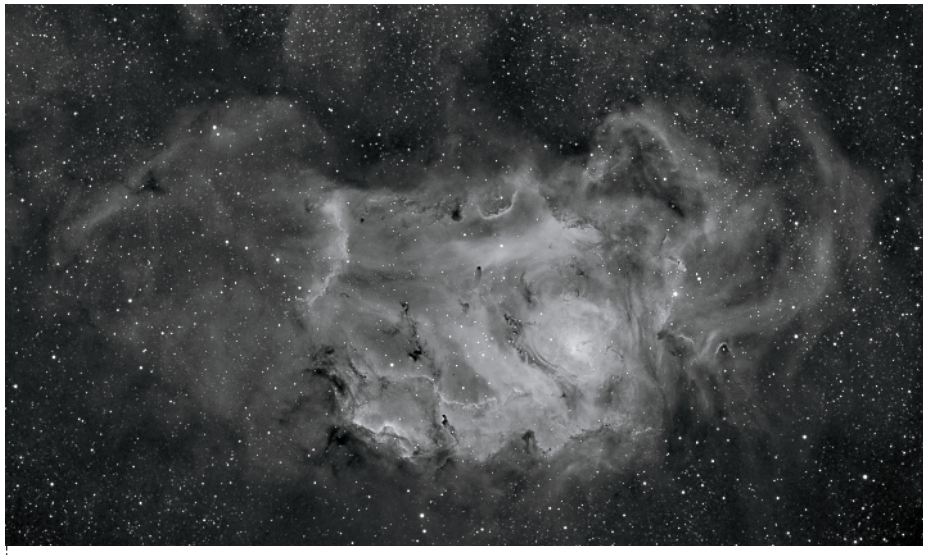
DRAWING THE LAGOON is not easy because of its subtle hues and areas of high and low contrast. In the 1830s, English astronomer John Herschel (1792–1871) sketched the Lagoon, seen here, from South Africa. MICHAEL E. BAKICH LIBRARY

▲ **THE LAGOON NEBULA (M8) lies within the boundaries of the constellation Sagittarius the Archer, not far from the point that marks our galaxy's center, from our perspective. Its size and brightness make it one of the top targets for amateur astronomers.** TONY AND DAPHNE HALLAS

M8 lies 5.5° west-northwest of Lambda, only 6.7° from the spot marking the galaxy's center, from our perspective. M8 also lies only about 8° from the ecliptic, which marks the Sun's apparent annual path through the stars. The Lagoon Nebula, in particular, is an incredibly active area, with howling interstellar winds, cosmic tornados, and star birth.

Historical observations

Like the Orion Nebula, which lies almost 180° away from the Lagoon Nebula, M8 is a stellar nursery visible without optical aid.



WHEN IMAGED through a Hydrogen-alpha (Hα) filter, the Lagoon Nebula's gas glows brightly. Hydrogen in the clouds absorbs ultraviolet radiation from nearby stars and reemits it as Hα light. The filter strongly blocks starlight, however, allowing scientists to better observe the nebula. THOMAS DAVIS

THIS IMAGE combines the light from three filters — Sulfur II, Hydrogen-alpha, and Oxygen III. Astronomers use such images to determine the relative brightnesses of nebulae at different wavelengths. Researchers took this image with the 24-inch (0.61m) Curtis Schmidt Telescope at Cerro Tololo Inter-American Observatory. R. BARBA/N. MORRELL ET AL. (UNLP)/CTIO/NOAO/NSF

WHEN ASTRONOMERS imaged the Lagoon Nebula with the 2 Micron All Sky Survey, they captured little of the red color from ionized hydrogen. The small reddish area at center is the Hourglass Nebula. The ultrahot star Herschel 36 ionizes the Hourglass. The more extended nebulosity glows primarily because of two stars, HD 165052 and 9 Sagittarii. 2MASS

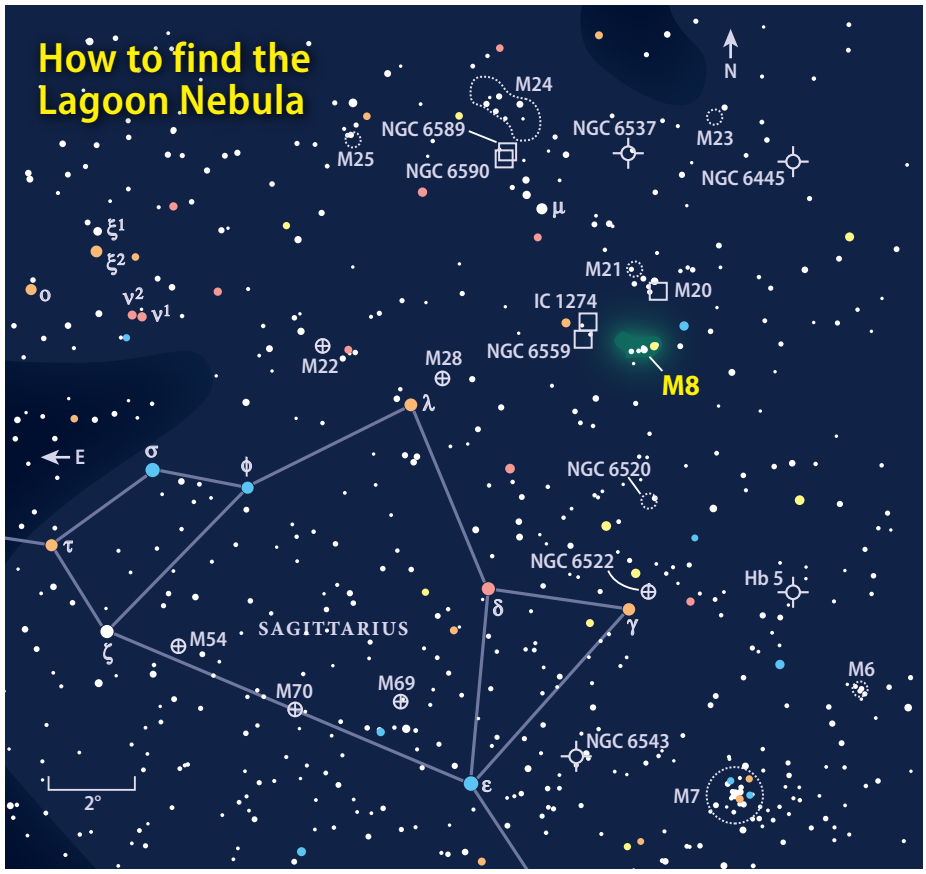
Greek philosopher Ptolemy (c. 90–168) and other ancient skywatchers undoubtedly glimpsed the hazy patch in the Archer's bow, although none of them mention it in their writings. Ptolemy did describe open cluster M7, which lies nearby.

With the invention of the telescope in 1608, astronomers' vision extended. Messier did not discover all of the objects on his famous list. Italian astronomer Giovanni Batista Hodierna (1597–1660) noted the Lagoon in 1654. Using a simple Galilean telescope that magnified about 20 times, Hodierna saw this fuzzy patch overlaid by a sprinkling of stars. Hodierna, however, made no mention of M8's nebulosity.

In 1680, England's first Astronomer Royal, John Flamsteed (1646–1719), cataloged NGC 6530 yet again. In 1747, French astronomer Guillaume Le Gentil (1725–1792) first described the nebula. Messier finally cataloged the nebulous object as number 8 in 1764.

He reported M8 appeared as "a large quantity of small stars: near this cluster is a rather brilliant star which is surrounded by a very faint light." English astronomer William Herschel (1738–1822) referred to "nebulosity of the milky kind" in his observing notes. It was William's son, John Herschel (1792–1871), who called M8 "a noble nebula," with "a collection of nebulous folds and matter surrounding and including a number of dark oval vacancies."

Many 18th- and 19th-century astronomers believed all nebulous objects would



THE EASIEST WAY to locate the Lagoon Nebula is to find the "teapot" of Sagittarius. The Lagoon lies 5½° west of the magnitude 3 star Kaus Borealis (Lambda [λ] Sagittarii), which marks the top of the teapot's lid. *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

resolve into stars through better telescopes. This mindset resulted, in part, when Galileo resolved the Milky Way's haze into countless stars. The nature of early telescopes prevented astronomers from observing faint, extended objects. With better equipment, our understanding of the Lagoon Nebula has grown significantly.

Lagoon physics

The nebula itself is huge. It spans 0.75°, which is larger than the Full Moon. M8 lies approximately 5,200 light-years away and measures about 140 light-years across. The Lagoon not only lies toward the central regions of the galaxy, but also in the galactic plane. On a clear, dark summer night, the Milky Way appears divided like a meandering river. These vast clouds of gas and dust are the building blocks of new stars.

The massive interstellar cloud that makes up M8 lies in an HII region. The gas is mostly hydrogen, the simplest of all elements, with one proton and one electron. When such gas clouds interact with young, hot stars, the hydrogen ionizes — ultraviolet radiation from stars as hot as 17,500° F (10,000 K) strips away electrons.

As hydrogen atoms recapture electrons, light with a reddish glow emerges, at least in photographs. Because the human eye is most sensitive to green light, through telescopes we generally detect only grays and dull greens in nebulae such as M8.

A great deal more is happening in the region of the Lagoon Nebula. John Herschel reported "oval vacancies" within M8. Some of these vacancies are small, dark areas call Bok globules, first described by Dutch astronomer Bart Bok (1906–1983). These regions are some of the universe's coldest places, with temperatures close to that of the cosmic background radiation: a mere –454° F (2.7 K). The globules are cocoons for the birthing of new stars. Bok globules are always found in HII regions.

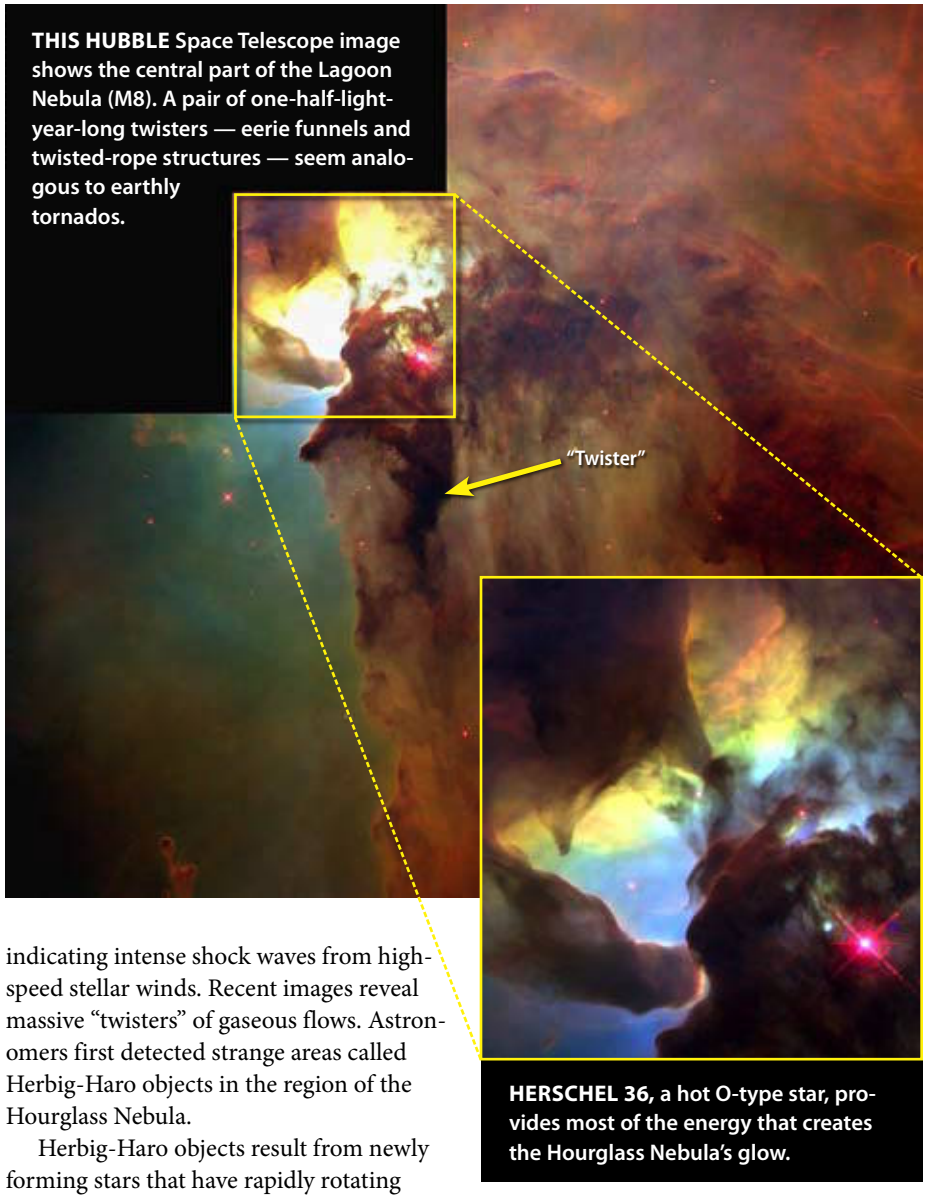
Deep within the Lagoon Nebula lies the much smaller Hourglass Nebula. John Herschel compared this area to the central core of the Andromeda Galaxy (M31). The area around the Hourglass is a hotbed of star formation. It's also active in other ways.

Hubble Space Telescope images show twisting and shearing of interstellar clouds, indicating intense shock waves from high-speed stellar winds. Recent images reveal massive "twisters" of gaseous flows. Astronomers first detected strange areas called Herbig-Haro objects in the region of the Hourglass Nebula.

Herbig-Haro objects result from newly forming stars that have rapidly rotating disks of gas spiraling into them. Narrow jets of plasma shoot out from the polar regions of these new stars. The jets interact with the surrounding interstellar medium and create bright patches, which astronomers detect as Herbig-Haro objects.

When Hodierna first examined the Lagoon Nebula, he mentioned a cluster of stars. This cluster carries the designation NGC 6530. This is a galactic, or open, cluster held together by the stars' mutual gravitational attraction. The Pleiades (M45) in Taurus is the best-known galactic cluster. Almost all single and double stars form within vast clusters such as NGC 6530. The clusters then slowly dissipate over time.

NGC 6530 contains about 100 young, hot stars. The average age of the stars is around 2 million years, making them Population I types. (The oldest stars in our galaxy are classified as Population II.)



THIS HUBBLE Space Telescope image shows the central part of the Lagoon Nebula (M8). A pair of one-half-light-year-long twisters — eerie funnels and twisted-rope structures — seem analogous to earthly tornados.

A. CAULET (ST-ECF)/ESA/NASA

HERSCHEL 36, a hot O-type star, provides most of the energy that creates the Hourglass Nebula's glow.

Population I stars, such as the Sun, lie mainly in the Milky Way's spiral arms. The stars in NGC 6530 are second- or even third-generation ones, but they have higher abundances of heavy elements — as much as 4 percent of their composition. NGC 6530 probably sits in front of the Lagoon Nebula, because the light from these stars shows little reddening from intervening galactic dust.

If you find yourself out observing on a warm, humid July night with a few mosquitoes buzzing in your ear, consider yourself lucky. Conditions could be a lot worse. As you peer through your telescope at M8, you're viewing one of the coldest and windiest spots in the galaxy. The Lagoon Nebula, the Hourglass Nebula, and NGC 6530 make up one of the most violent and complex objects you'll see anywhere in space.

Raymond Shubinski *is the director of Science City/Attractions in Kansas City, Missouri, and a devoted summer-sky observer.*

ASK ASTRO

This month:
- What happens on Earth as the Moon recedes?
- Is gravity leaking into our universe?
- Can astronauts travel back in time?

DISTANT MOON

Q: With the Moon gradually moving away from Earth, what will happen to people and objects when the Earth-Moon center of mass reaches Earth's surface? — **MICHAEL HANLEY,** NEW HAVEN, CONNECTICUTT

A: Nothing will happen. The barycenter, or the Earth-Moon system's center of mass, is a mathematical construct used to help us understand the system as a whole.

In order for a location in space to exert a gravitational pull, it must have some mass or substance, and the barycenter has none, being a mathematical fiction. Your weight is determined by Earth's gravitational pull, which is directed toward Earth's geometrical center — the barycenter of the Earth-Moon system has no influence on people or objects.

It's true the Moon (and the Sun and other solar system objects) does exert a slight gravitational "tug" on you, but this is vanishingly small — the effect of the Moon is only 3 millionths that of Earth. And because of Earth's rotation and the relative motion of these other bodies, such effects average out over time. — **BILL COOKE,** NASA/MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA

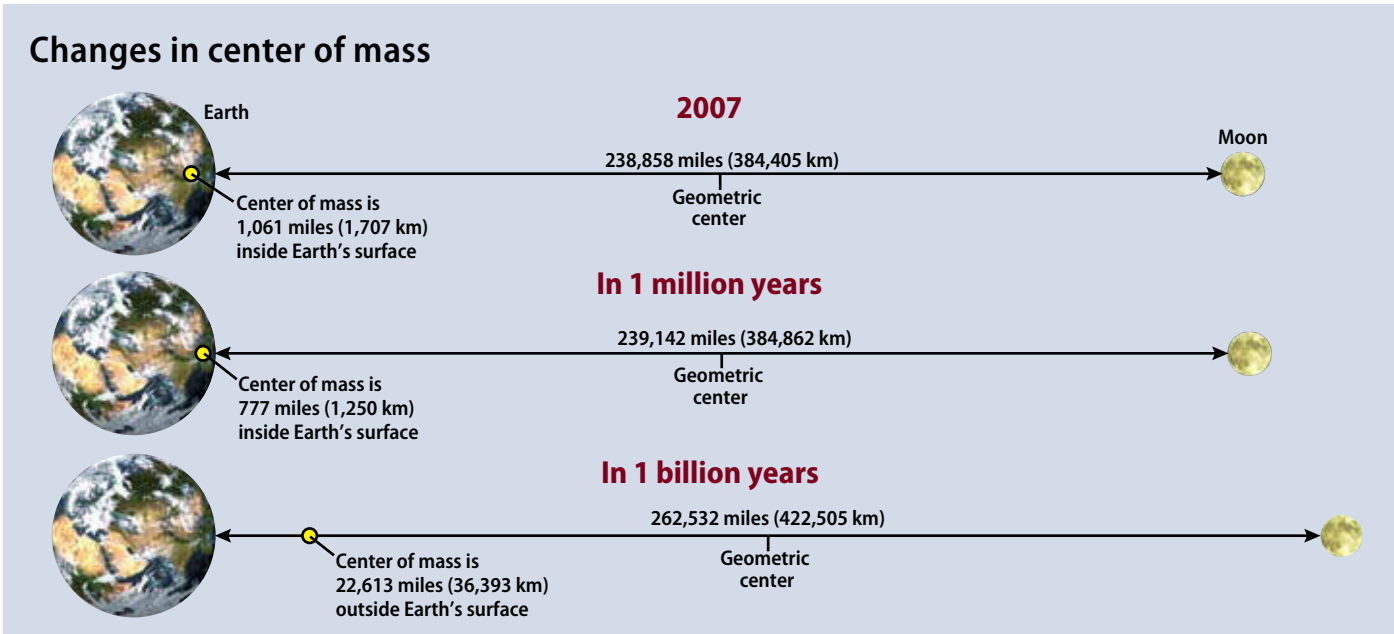
LEAKING GRAVITY

Q: If gravity can leak out of our universe, is it possible gravity is leaking into our universe in a similar manner, causing effects attributed to dark matter? — **JAMES SPRINGER,** EFFORT, PENNSYLVANIA

A: Cosmologists have no evidence whatsoever that gravity — or anything else, for that matter — can "leak" out of, or into, our universe. The universe is everything around us, including parts of it that are so far away, we will never be able to see them. While it is possible for an object to be beyond our observable horizon — farther away than about 50 billion light-years — we don't know, even in principle, how something could be beyond our universe.

However, cosmologists are studying the possibility that our universe contains more spatial dimensions — one or a few dimensions that, despite evidence to the contrary, exist in addition to the three familiar ones. If these hypothetical "extra" dimensions exist, it is possible that no material object can probe them.

Some scientists suggest gravity, and gravity alone, could, perhaps, expand into extra dimensions. In this case, the gravitational field observed by a person in 3-D would be diluted because much of it would disappear into the extra dimensions. This is much like


Changes in center of mass
2007
Earth
Moon
238,858 miles (384,405 km)
Geometric center
Center of mass is 1,061 miles (1,707 km) inside Earth's surface
In 1 million years
239,142 miles (384,862 km)
Geometric center
Center of mass is 777 miles (1,250 km) inside Earth's surface
In 1 billion years
262,532 miles (422,505 km)
Geometric center
Center of mass is 22,613 miles (36,393 km) outside Earth's surface

THE EARTH-MOON barycenter, or center of mass, moves closer to Earth's surface as the distance grows between the two bodies. The gravitational effect on earthlings is negligible. *ASTRONOMY*: ROEN KELLY

a water jet from a garden hose, which is strong because the hose ejects water along one dimension (the length of the hose). But when the hose is attached to a water sprinkler, the same total amount of water is scattered in three dimensions, rather than one, which dilutes the water jet. The concept of gravity leaking from extra dimensions into our three dimensions is equivalent to the leakage the other way around — the gravity is present everywhere, and what matters is that its pull weakens if it operates in more dimensions than three.

Weakening of gravity due to its leakage to extra dimensions is a hot research topic because it could explain the surprising discovery that the universe's expansion is speeding up. The apparent weakening of gravity due to its leakage can create this speeding-up effect, even if the universe's expansion is not actually accelerating.

The jury is still out on the existence of extra dimensions, but the Large Hadron Collider particle accelerator — run by the European Organization for Nuclear Research, known as CERN — which will begin operating this year near Geneva, Switzerland, may be able to find them indirectly by carefully studying the debris of particle scatterings. — **DRAGAN HUTERER,** KAVLI INSTITUTE FOR COSMOLOGICAL PHYSICS, UNIVERSITY OF CHICAGO

TIME TRAVEL

Q: Does time slow down as a spacecraft approaches the speed of light, thus allowing the craft to travel back or forward in time? — BRETT BILLMAIER, TEMPERANCE, MICHIGAN

A: Theoretically, time would slow down, and, in effect, a craft could fly into the future. The concept of flying into the past is much less clear.

According to Einstein's theory of special relativity, if someone travels at close to the speed of light, time slows. This has been verified by many experiments. These experiments show elementary particles (such as the muon) live much longer when they move at speeds close to the speed of light than when their lifetimes pass at rest.

ASTRONOMY: ROEN KELLY

THE DAYS OF OUR LIVES tick by with unrelenting regularity. Yet, many physicists think the day will come when we can travel into the future, and maybe even into the past.

If astronauts travel at such speeds and then return to Earth, they may find they have aged much less than those who stayed on Earth: While they may have aged by only one year, people on Earth might have aged by 50 years. This allows for the possibility, theoretically, for astronauts to travel into the future.

Special relativity does not allow time travel into the past. **The theory of general relativity may allow time travel into the past, but it is not clear yet whether those mathematical solutions could apply to macroscopic bodies, and, in particular, to people.** Those solutions do not depend at all on the speed of the traveler, but are rather based on the warping of space-time. They raise some intriguing, unresolved paradoxes. — **MARIO LIVIO,** SPACE TELESCOPE SCIENCE INSTITUTE, BALTIMORE

IN THE KNOW

BARYCENTER
The center of mass of a two-body system like the Earth-Moon system.

MUON
A negatively charged elementary particle.

SPEED OF LIGHT
The speed light travels in a vacuum; 186,000 miles per second (300,000 km per second).

COMING NEXT MONTH ...
Do black holes ever disappear? Post your comments about this question online at www.astronomy.com/forums.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

AMAZING OBSERVER

Celebrated for his mastery of deep-sky observing, Brian Skiff is also one of the most amateur-friendly astronomers. /// BY DANIEL PENDICK

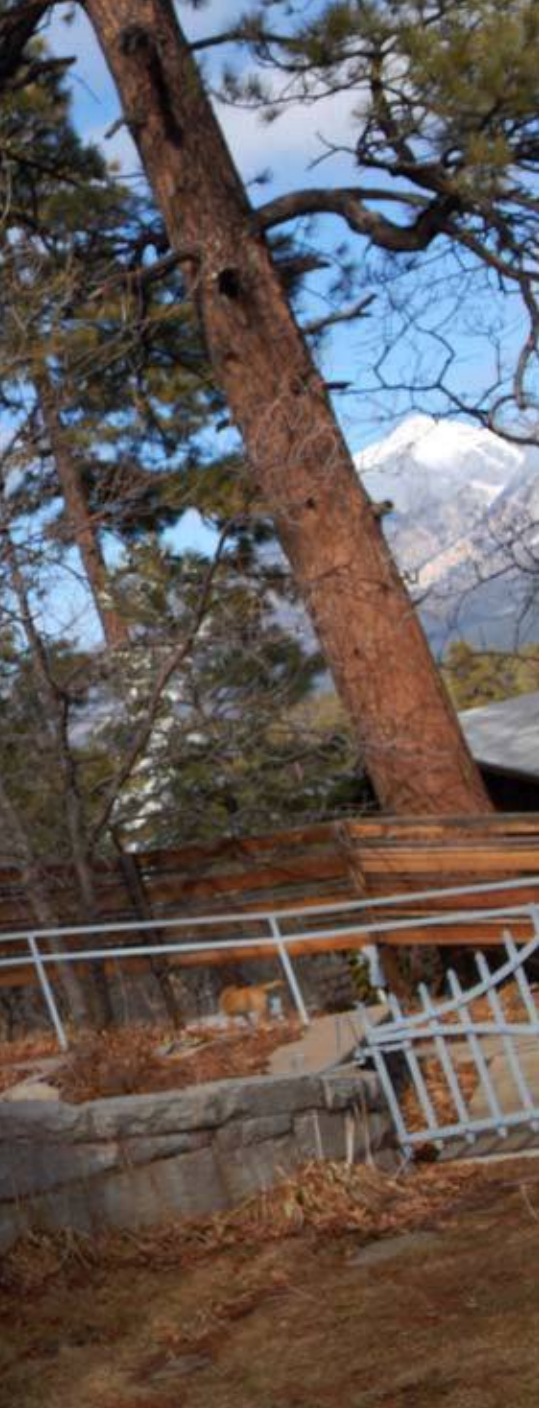
Starry virtuoso

It's dusk at Anderson Mesa, Lowell

Observatory's dark-sky site southeast of Flagstaff, Arizona. Excited by the prospect of exceptional seeing, local amateur observer Jeremy Perez sets up his 6-inch Newtonian. Nearby are Rick Angell and Gary Nielson, fellow stargazers in from Colorado. Perez points his 6-inch Newtonian telescope at the Andromeda Galaxy, rising high in the northern sky. Within its fuzzy outlines lies an even fainter patch of light: NGC 206, a magnificent star cloud floating in Andromeda's dust lanes. Perez carefully inserts an eyepiece into his telescope and starts to sketch the star cloud.

LOWELL OBSERVATORY'S Brian Skiff has logged countless hours of professional observing but maintains close ties to amateurs. Here he stands near the mausoleum of observatory founder and namesake Percival Lowell. JAKE BACON

A fireball — the first of three this night — streaks out of Taurus. Moments later, a lone figure materializes from the darkness, as if summoned by the bolide's flash. It's Brian Skiff, a research assistant at Lowell Observatory. "Did you see the fireball?" he asks. Skiff is on an all-night run at the Mesa using the observatory's 24-inch Schmidt reflector to look for asteroids whose orbits could cross Earth's. When the sky is clear,



Skiff observes several nights per week for the Lowell Observatory Near-Earth Object Search (LONEOS).

Skiff dresses in light, slightly rumpled slacks and a casual fleece jacket. He wears his hair long and combed to the side, reminiscent of the 1970s, the decade in which he began working at Lowell. Although Skiff has been a professional observer for 30 years, his origins in amateur astronomy go back even further, to a childhood glimpse into the Milky Way through a neighbor's dime-store refractor.

Skiff chats with Jeremy and the other visitors for a short time and then asks, "Would you like to see the dome?"

STARS SHINE over the dome housing the 24-inch Schmidt telescope that Lowell Observatory astronomer Brian Skiff uses to hunt for asteroids that might someday cross paths with Earth. JEREMY PEREZ

Virtuoso of the telescope

By the time Skiff graduated in 1977 with a degree in physics from Northern Arizona University, he was already working at Lowell. He and his college observing partner, Christian Luginbuhl, spent 6 months using the observatory's 42-inch telescope to measure the diameters of large, bright stars.

Skiff's passion for astronomy is matched only by his love of music. In 1979, he returned to campus for what he calls "five semesters of masochism" studying music theory and composition. He tried to master piano, guitar, flute, and vocal performance, but eventually gave up in frustration. "My appreciation for the music was far in excess of what I could really play," he admits.

Instead, Skiff became a virtuoso of the telescope. In the prime of his amateur observing days, Skiff would explore the sky with a feverish intensity, says friend and amateur astronomer Tom Polakis. "He would go out and observe 60 or 70 objects in a night very methodically, and not with a lot of talking and shooting the bull."

Skiff cruised the astronomical library at Lowell with the same zeal, augmenting his mental catalog of deep-sky objects with what scientists knew about them. To top it off, he shared his growing knowledge freely. The astronomer also reached out to amateurs as a frequent contributor to *Deep Sky Monthly* and *Deep Sky* magazine, the now-defunct publications founded and edited by David Eicher, who is now the editor of *Astronomy* magazine. Today, Skiff continues to be very active on amastro, a Yahoo! discussion group popular with advanced amateur observers. He is known for writing clear and informative responses to questions posted by members — sometimes within minutes of receiving them.

Skiff mixes with amateurs and professionals with equal ease and enthusiasm. "He loves astronomy so much that he has devoted his life to both sides of it," says Harold Corwin, an astronomer at Caltech who has known Skiff for 30 years. "He's a professional, of course, in a sense that he's paid to do it. But he's also an amateur because he does it because he wants to. Brian's got the best of both worlds."

Texas Star Party days

In the early 1980s, a novice deep-sky observer named Barbara Wilson was attending her first Texas Star Party. By the time Wilson joined the party, she says, Skiff had achieved "guru status" among the amateurs attending the event. He gave talks and impressed people with his jaw-dropping command of the scientific literature. Wilson was outside one night at her telescope as Skiff walked by.

"What are you looking at?" he asked her.

"An IC galaxy."

The *Index Catalog* (IC) is a supplement to the legendary *New General Catalogue of Nebulae and Clusters of Stars,* usually referred to as "the NGC." After the deep sky's glittering galactic gems were enshrined in the NGC, the IC functioned as a junk drawer for lost, faint, and obscure deep-sky objects.

But to amateurs like Wilson, the IC represented challenging and fresh targets. To find them meant you were good; to even *want* to find them indicated something bordering on fanaticism.

Skiff was obviously pleased that Wilson was off the beaten track. "Oh great! You're not just looking at the Messiers or the bright NGCs," he said.

Wilson recalls that Skiff lingered, asking questions to focus her on important observing points. What do you see? How

THE LEGENDARY "PLUTO PLATE" **Skiff peers through in this photo preserves the faint image of the distant solar-system denizen — recently reclassified as a dwarf planet — that Clyde Tombaugh discovered in 1930 while working at Lowell Observatory.** JAKE BACON

JEREMY PEREZ

SKIFF maintains close connections with both amateur and professional astronomers. Here he is shown at the Coconino Astronomical Society in Flagstaff, Arizona, with astronomer Carolyn Shoemaker (left) and amateur comet-hunter Don Machholz.

bright is it? Does it look different from other galaxies? Do you see spiral arms?

"He asked questions that made me look harder," explains Wilson, now managing director of the George Observatory at the Houston Museum of Natural Science. "He helped me learn how to see. He was willing to spend a precious half-hour of dark time sitting next to a complete novice."

Skiff continues his mentoring via amastro. Since the late 1990s, he has posted thousands of messages on the site. "There's just no one else out there that I think has been as giving with his time," Wilson says.

Asteroid-hunter

On observing days, Skiff rises "at the crack of noon" and goes to his office on Mars Hill to prepare for asteroid-hunting. At night, he aims the Schmidt telescope toward parts of the sky where he is most likely to find near-Earth asteroids (NEAs) — and where the other survey projects might not be looking. There's good-natured competition among asteroid-hunters, but, in the end, LONEOS is outgunned by better-equipped efforts such as the Lincoln Near-Earth Asteroid Research (LINEAR) program. "We're sort of the runt of all the surveys," Skiff cracks. But if LONEOS has managed to give LINEAR healthy competition, it's in large part due to Skiff's skill and experience. "Brian is a very keen observer," says LONEOS' chief astronomer, Ted Bowell.

LONEOS can cover up to 1,000 square degrees of fresh sky per night, with each patch of sky observed up to 4 times. Software compares the multiple images and identifies objects that appear to be moving. Another program then calculates tentative orbits for the objects based on reasonable assumptions of their likely geometry. Then Skiff takes over.

Like the other scientists Skiff has worked with over the years, Bowell has only praise for his colleague. Hunting for NEAs demands a combination of skills. "It's experience, good judgment, and, above all, enthusiasm for the discovery process," he says. "If you lose that, then you might as well not bother to observe. Brian has all of those good attributes."

For a lifelong visual observer, getting paid to hunt for asteroids is a pretty good gig, but Skiff's enthusiasm has its limits. Now in his fourth decade of professional observing, Skiff says staying up all night "is not getting any easier." Although his duties at Lowell remain satisfying, he has another ambition: to correct scores of mistakes and inaccuracies in the catalogs and databases holding the collected observations of generations of astronomers and spacecraft.

Getting it right

Throughout the 1970s and 1980s, Skiff and Chris Luginbuhl labored on their magnum opus, the *Observing Handbook and Catalogue of Deep-Sky Objects.* Finally published in 1990, it featured descriptions of 2,050 deep-sky objects. Every entry rests upon actual observations and detailed research in the scientific literature. Deep-sky fans, not surprisingly, were pleased. "The collection of observations in there isn't as uniform as we might like it, but at the time it was the cat's meow," Skiff says.

The book also marked the end of Skiff's interest in amateur observing. His last major field trip was to Las Campanas Observatory in Chile with Tom Polakis.

"I did a good chunk of the southern sky with a 6-inch refractor, sort of working toward a southern volume of the observing handbook," he recalls. "I got back up here and tried observing some more and thought, 'I don't want to do this anymore.' I'd been there, bought the T-shirt, the whole deal. I wanted to do something else."

Skiff's work on the book and at Lowell had exposed him to the universe of astronomical data, both in print and online. As Skiff poured over the record, he came to a disturbing realization.

"A lot of people tended to look in the old catalogs and take whatever was there at face value and not even check on the sky to see whether it was even close to being right," Skiff says. "We made the mistake of actually checking on these things and found that a lot of it was just plain wrong."

Daniel Pendick *is an associate editor of* Astronomy.

Objects were misclassified, or were classified based on data a half-century out of date. Often the sky coordinates were way off. Skiff's passion for accuracy, he says, "sort of grew from there."

It was a good thing for Brent Archinal and Steve Hynes that Skiff took such an interest in astronomical correctness. In the 1990s, Archinal and Hynes began to catalog star clusters. They thought it would take a year; it consumed a decade. Skiff proved a helpful copilot for navigating the seas of conflicting, incomplete, and incorrect astronomical information, Archinal says.

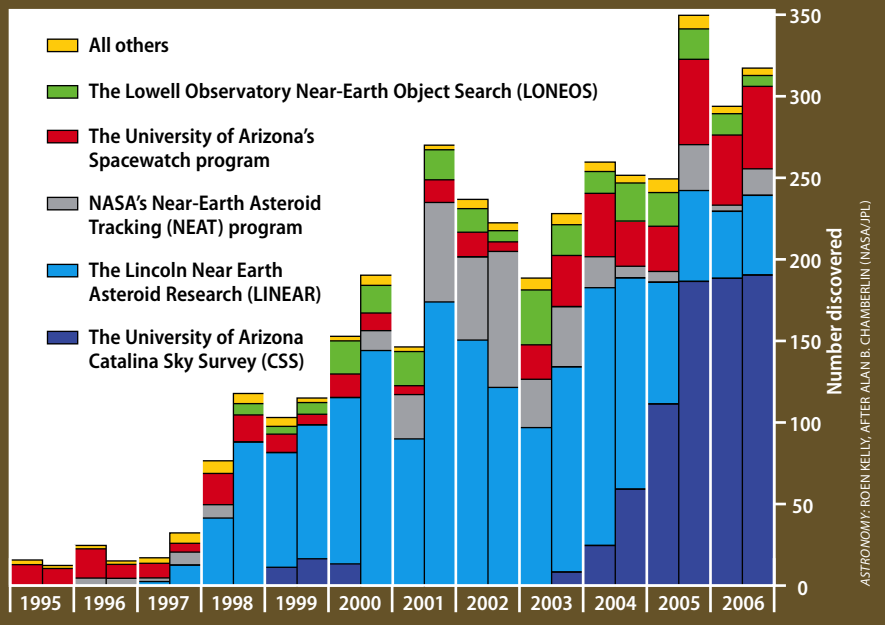
Case in point: They asked Skiff about Collinder 399, a group of stars in the constellation Vulpecula also known as Brocchi's cluster, Al Sûfi's cluster, or the Coathanger cluster. It was once thought to be an open cluster whose stars were loosely bound by gravity. But Skiff examined data from the European Space Agency's Hipparcos satellite and determined that Collinder 399 is actually an asterism — a group of stars in the same spot in the sky, but unrelated to each other in any physical sense.

Skiff has made significant contributions to refining the massive online SIMBAD database. Managed by the Centre de Données astronomiques (CDA) in Strasbourg, France, SIMBAD contains information on an enormous number of astronomical objects — nearly 3.8 million to date. Skiff spent a paid summer in Strasbourg in 1995 helping edit the database.

He acknowledges that spending so much time perfecting the cosmic card catalog, almost always without pay, reflects a psychological itch that he is compelled to scratch. "Probably I should have been an accountant or bookkeeper," Skiff notes dryly. But there is a higher purpose to the obsession with clean and tidy star catalogs. "It's the same thing he and I have been obsessed with through our careers," says Harold Corwin, a fellow astronomical cataloger. "The data have to be right or the science isn't going to be. That, I think, has been one of Brian's really strong points throughout his career as an astronomer. He's insisted that we get the data right."

IN THE 1980s, Skiff (left) enjoyed guru status at the popular Texas Star Party. Here he is shown at the TSP in 1983 with friend and fellow observer Dave Eicher, now editor of *Astronomy*. DAVID J. EICHER

Near-Earth asteroids discovered since 1995



FIVE MAJOR SURVEYS and a number of smaller efforts are under way to identify asteroids 1 kilometer or larger that present a potential threat if they collide with Earth.

Unfortunately, making a living working on catalogs and databases isn't easy. "It's not science, it's bookkeeping," Skiff explains. "It's hard to get money to do it." But that hasn't stopped him. He continues to send files of updates and corrections to France.

"I have a long laundry list of things to do," Skiff says. "I can't spend all of my time on it because I would go crazy — even me. I've been working on it pretty steadily since that visit to Strasbourg, 12 years ago now, but there's another 10 or 20 years left."

Long night

Rick and Gary follow Skiff to the LONEOS dome for their tour while Jeremy keeps watch on the equipment. Forty-five minutes later, it's Jeremy's turn, so he and Rick tread carefully through the darkness of the ponderosa pines that carpet the Mesa. They pass through an outer entry to the observatory and then through a second door into the warm light of the LONEOS control room. They hear intermittent whirrings from the dome as Skiff uses the Schmidt telescope to survey the sky in hopes of detecting faint, moving points of light — among them asteroids that could someday threaten the human race. It's a dire task that seems out of synch with a peaceful evening on the Mesa.

Skiff starts the tour. The green monitor in front of him displays the telescope's controls and vital signs. A workstation on his left pipes in live images from the telescope. On Skiff's right, a monitor displays smaller slices of the main images with suspected NEAs bull's-eyed by green circles alongside data on their orbits and brightnesses. Most of the "hits" on display, Skiff explains, are phantoms — glints of galaxies, diffraction spikes from bright stars, random electronic chirps from the camera's CCD element.

By the end of the night, Skiff may have to sort through as many as 5,000 images to find a single faint NEA. Jeremy and Rick watch attentively as Skiff plays the data on his keyboards like a church organist.

ONLINE EXTRA Read Brian Skiff's classic essay on the darkness of the night sky at www.astronomy.com/toc.

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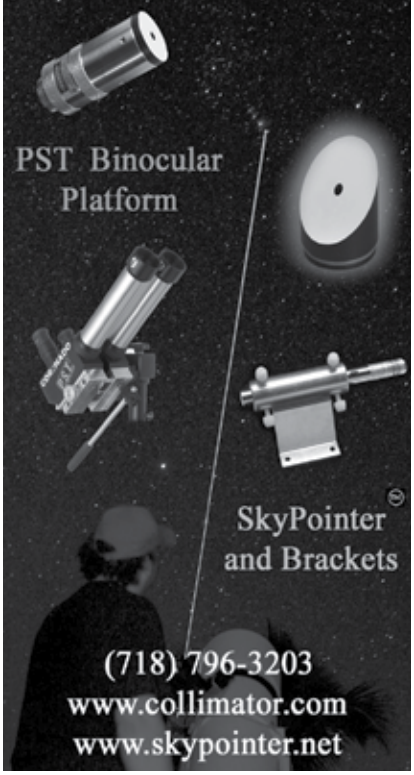

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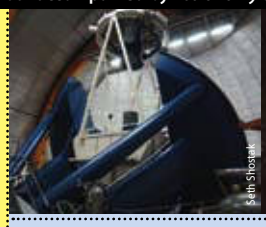

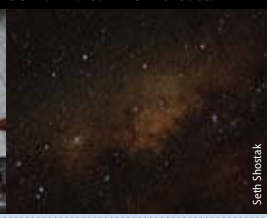

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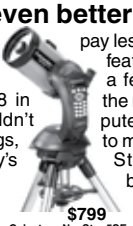

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Finger Lakes Instrumentation's MaxCam ME2 CCD camera offers a host of features in a small package. /// **BY DAVID HEALY AND BRUCE GARY**

MaxCam gets imagers started

Ready to get started astroimaging but don't know where to begin? Try Finger Lakes Instrumentation's (FLI) MaxCam ME2. This small, full-featured CCD camera's high-quantum-efficiency, front-illuminated Kodak sensor and 15-micron read noise are sure to please aspiring astroimagers.

The versatile ME2 comes with installation instructions and camera-control software on a CD-ROM. This CCD camera, which imagers can operate by third-party software such as *MaximDL*, *CCDSoft*, *Astroart*, and *Vista*, operates on Windows XP, Windows 2000, or Linux platforms using a USB interface.

The ME2 comes with a USB interface and cable, power supply, power-supply line cords, and a tripod mount. The camera's nosepiece is compatible with a 2-inch eyepiece holder. Options include Finger Lakes' DF-2 digital focuser and five filter sets, ranging from the standard 28mm LGRB set to the 50mm UBVRI set. The camera's external shutter takes exposures as short as 0.03 second.

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David Healy, *a contributing editor to* Astronomy, *has discovered more than 460 minor planets from his Arizona observatory.*
Bruce Gary, *retired from NASA's Jet Propulsion Laboratory, specialized in lunar radio astronomy, aviation safety, and the atmospheric sciences.*

SPIRAL GALAXY NGC 2903 in Leo shows long, wispy spiral arms and a bar running diagonally across its midsection in this MaxCam ME2 CCD image. LORENZO COMOLLI

FLI'S MAXCAM ME2 captured the colorful bulge of edge-on spiral galaxy NGC 891. The ME2 easily reveals the galaxy's dark dust lane. LORENZO COMOLLI

THIS ME2 IMAGE shows globular cluster M3 in Canes Venatici. Showy M3 is a popular target with many amateur astronomers. LORENZO COMOLLI

the highest sensitivity available in front-illuminated CCD cameras. The chip's read noise of 15 electrons RMS is typical for CCD chips used for astronomy.

Keep it cool

CCDs must be cooled during operation — each 11° F (6° C) drop in the camera's operating temperature roughly halves the level of electronic noise in the system. Noise degrades image quality, so the less noise in the detector, the better.

The MaxCam's settable, fan-assisted integral cooling system, according to our tests, brings operating temperatures some 54° F (30° C) below ambient temperatures — adequate for the operating circumstances most amateurs will encounter. While we didn't test the water-assisted cooling system, the basic air-cooling system impressed us.

Matching the CCD to your scope

The ME2's "binning" capability gives it flexibility. The instrument's relatively small, 9-micron-sized pixels can be combined electronically into 2x2 or 3x3 arrays. This converts the camera's 9-micron pixels into 18- or 27-micron pixels, respectively. Binning is important when effectively combining your CCD and telescope. The larger binned pixels are more sensitive than the CCD camera's full-resolution 9-micron pixels.

One basic rule a new CCD owner should follow to get the most out of the ME2's high resolution and sensitivity is the "half the seeing" rule. A CCD-telescope system's angular resolution should approximate "half the seeing" of the location where the system is operated. For example, many observing sites suffer from atmospheric turbulence to the degree that the typical "full-width half-max" — a measure of how finely resolved a digital star image — of star images is no better than about 4". According to our rule of thumb, a CCD-scope system operating in such a location should have an angular resolution of about 2".

"Plate scale," or your CCD's angular field of view, is a simple formula that can help match your CCD camera to your telescope: The plate scale, in arcseconds, of a single pixel can be calculated as 8.12 x (pixel size in microns)/(system's focal length in inches).

Thus, if you attach your ME2 with its 9-micron pixels to a 12-inch f/10 telescope with its 120-inch focal length, the plate scale of the system is 0.6" per pixel. This wastes much of the ME2's high resolution, according to the "half the seeing" rule. If you bin your images 3x3, however, the resolution of the system becomes 1.8" per binned 27-micron pixel, much closer to half your site's average seeing. Although binned pixels have higher sensitivity than unbinned ones, the resulting image suffers from the appearance of poor resolution because a 3x3 binned image with this CCD consists of an array of only 256x170 pixels.

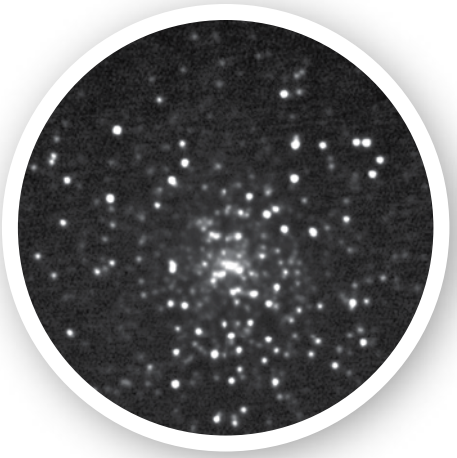
By contrast, if you attach your ME2 to an 8-inch f/4 scope with a 32-inch focal length, the formula — using unbinned, 9-micron pixels — yields a resolution of 2.3" per pixel, neatly matching the guideline.

These calculations lead us to conclude the MaxCam ME2 is best suited for use with smaller scopes.

Field of view on the sky

A significant issue with small-chip CCDs, such as the ME2, is their limited fields of view. Many deep-sky objects popular with

A FAN-ASSISTED cooling system maintains the CCD's operating temperature at about 54° F (30° C) below ambient.



GLOBULAR CLUSTER M15 in Pegasus is one of the Milky Way's most densely packed globulars. M15's small central core spans about 1.4 light-years. The authors used Finger Lakes Instrumentation's MaxCam ME2 CCD camera to capture this image of M15.

THE MAXCAM ME2 CCD CAMERA captured this image of the Crab Nebula (M1), which appears to float like an ephemeral cloud. Supernova remnant M1 began expanding when a star exploded as a supernova. Observers witnessed the event in 1054. DAVID HEALY/BRUCE GARY

THE WHIRLPOOL GALAXY (M51) appears face-on in this composite image, taken with the ME2 attached to a 7.8-inch f/10 Schmidt-Cassegrain telescope. This LLRGB image comprises exposures of 200, 120, 30, 30, and 45 minutes, respectively. LORENZO COMOLLI

amateur imagers won't fit into the ME2's field of view if the CCD is fitted to a long-focus instrument, such as a 12-inch f/10 scope. A small field of view also makes finding and focusing on a target a challenge. If each pixel images 0.6" on the sky, the ME2's 762x512 array will cover a rectangle only 7.6' by 5.1'. The Dumbbell Nebula (M27), for instance, well exceeds 7' in diameter; the Whirlpool Galaxy (M51) is 11' by 7'; and the Andromeda Galaxy (M31) subtends at least 3° by 2°.

The ME2's narrow-field limitations can be overcome, in part, by mounting it on a short-focus telescope. Further, several telescope and accessory manufacturers offer focal-reducing lenses, also known as telecompressors. Mounting a 0.5x telecompressor between the ME2 and your telescope accomplishes two things: It doubles the camera's field of view, measured linearly, or quadrupled in terms of area coverage, and the telescope's f-ratio becomes "faster." For extended objects, such as nebulae, a faster f-ratio translates to shorter exposure times for the same image brightness. For stars, however, the benefit is small, especially if sky brightness is more of a factor than CCD dark-current noise. The downside to using a telecompressor is that you introduce another element into the optical path. Also, color filters (RGB or BVRI) will require slightly different focus settings with a telecompressor.

Getting the best out of the ME2

Although the ME2 does not have autoguiding capability, it can be used with full effectiveness if the telescope mount has excellent tracking. Less than perfect tracking can be overcome somewhat by accumulating and combining many short exposures (i.e., 15 to 30 seconds). The main disadvantage of this technique is increased electronic read noise in the images.

The ME2's best use may well be as a piggybacked wide-field imager. The CCD comes with a standard camera-tripod socket. Attach a standard piggyback mount and an illuminated-reticle guiding eyepiece to your telescope, and it becomes the ME2's guidescope. Attach a camera lens to the CCD — an adapter may be required, depending on the type of lens you're using — and you have a wide-field imager. A standard 50mm camera lens can capture a quality image of a 5° by 8° area of the sky with an exposure of less than a minute. Even in less-than-perfect skies, piggyback wide-field imaging may well prove rewarding.

Finger Lakes Instrumentation's MaxCam ME2 CCD camera is a good choice for beginning astrophotographers who plan to image with a small, short-focus telescope. The ME2's external shutter takes exposures as short as 0.03 second, which makes it suitable for snapping a bevy of images and then combining the best frames to create a composite image. Or utilize the camera's high sensitivity for piggybacked wide-field imaging. To get the most out of Finger Lakes Instrumentation's MaxCam ME2 CCD camera, be sure to match it with the right telescope.

THE MAXCAM ME2 front-illuminated CCD camera utilizes a Kodak KAF-0402ME chip as its main electronics, housed in a stainless-steel camera body. The full-frame CCD has 768x512 active pixels. Pixel size is 9x9 microns.

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Antique telescopes, globes, and astrolabes fill the exhibit halls of Chicago's Adler Planetarium. /// **BY MICHAEL E. BAKICH**

The brass and glass of astronomy's past

Astronomy's history spans millennia.

Only in the last thousand years, however, have skywatchers had instruments to help them. Some of the most fascinating such mechanisms are displayed at the Adler Planetarium and Astronomy Museum on Chicago's lakefront. In fact, the facility boasts the Western Hemisphere's largest collection of astronomical artifacts.

THIS CANNON DIAL was practical and entertaining. Built in France around 1800, it focused sunlight onto a charge, which ignited. When oriented correctly, the cannon fired at noon. ALL IMAGES COURTESY ADLER PLANETARIUM AND ASTRONOMY MUSEUM

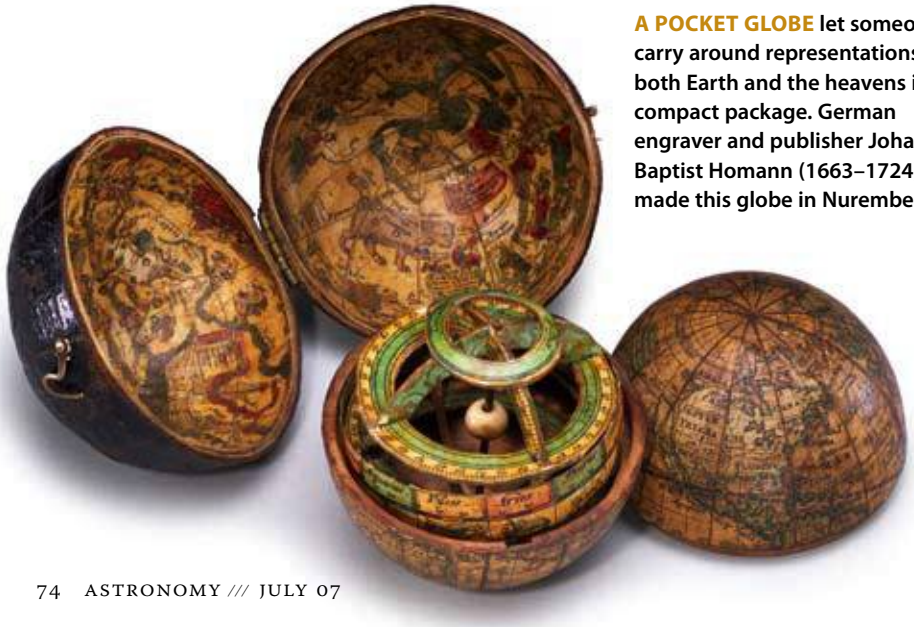
First in the West

The Adler was the Western Hemisphere's first planetarium. American musician, businessman, and philanthropist Max Adler (1866–1952) founded it in 1930, only 7 years after the world's first planetarium went into operation in Munich, Germany.

But Adler wanted to present more than planetarium sky-shows under a dome. He thought the history of astronomy was important enough to share with the public. So, in addition to the planetarium's star projector, he purchased some 500 astronomical, navigational, and mathematical instruments from antique dealer Anton Mensing in the Netherlands. These instruments formed the foundation of the Adler's Webster Institute for the History of Astronomy. Today, the collection houses nearly 2,000 historic instruments.

Managing history

The planetarium's primary collection dates from the 12th century. Adler's oldest object, however, is a terra-cotta brick with a Sumerian relief of a lion — a mythographic representation of the constellation Leo. The brick was made between about 2500 B.C. and 1800 B.C.



A POCKET GLOBE let someone carry around representations of both Earth and the heavens in a compact package. German engraver and publisher Johann Baptist Homann (1663–1724) made this globe in Nuremberg.

Marvin Bolt, director of the Webster Institute for the History of Astronomy, is one of three permanent staff members who manage the collection. Several additional curators also help maintain the artifacts.

The collection contains examples of almost every type of astronomical apparatus — astrolabes, armillary spheres, celestial globes, nocturnals, orreries, sundials, and telescopes. It also includes mathematical, navigational, optical, and surveying devices. The oldest instrument is an astrolabe dated to 1130.

More than instruments

Since its inception, Adler's collection has grown in stages. In addition to the Mensing Collection, Adler purchased several hundred additional instruments from a fund

Michael E. Bakich *is a senior editor of* Astronomy.

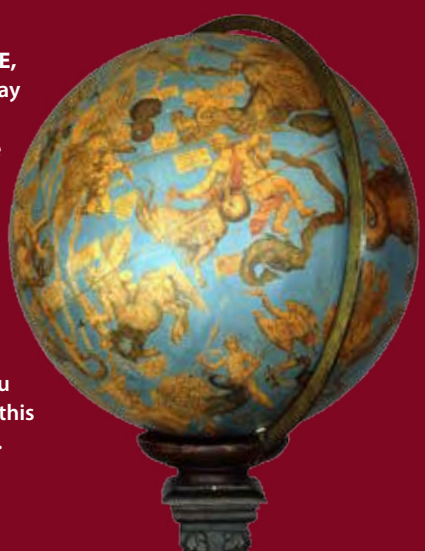
THE CELESTIAL GLOBE recreates the starry sky from an imaginary point far from Earth. This European globe dates from 1480, with alterations made between 1550 and 1580.

AN ORRERY is a model of the solar system. This intricate mechanism shows the motions of the planets (and, sometimes, their satellites) as they orbit the Sun. British astronomy popularizer and instrument-maker James Ferguson may have constructed this instrument for King George III around 1780.

A CUBE DIAL could be confusing to use. A compass oriented the cube, which had five symmetrically placed sundials on its surfaces. German instrument-maker David Beringer (d. 1756) constructed this sundial.

A GARDEN SUNDIAL remains outside. Such a permanent sundial worked only at a specific latitude. This German garden sundial dates from the late 17th to early 18th centuries.

ONE OF THE JEWELS of the Adler collection is this Italian telescope, dated to 1630. This instrument, whose maker is unidentified, is one of only six known telescopes made before 1650.



AN INEXPENSIVE, but complicated, way to make a celestial globe was to create hand-colored paper star maps called gores. The globe-maker then glued the gores to a wooden frame. Amsterdam mapmaker William Blaeu (1571–1638) made this globe around 1630.

A TELLURIAN shows the motion of Earth (and often the Moon) around the Sun. In this model, made by Prague instrument-maker J. Feckl around 1900, a candle occupied the Sun's position. The reflector concentrated its light on the Earth model.

THIS ORRERY, constructed by London instrument-maker Benjamin Martin between 1750 and 1780, shows the relative motions and positions of the planets out to Saturn with their then-known moons. This instrument operates from a wind-up spring mechanism.

SIR WILLIAM HERSCHEL (1738–1822) discovered Uranus, determined the direction the solar system moves through space, and built telescopes. He made this speculum-mirror reflector in Bath, England, in 1788.

THE CROSS-STAFF originated in the 1300s. By placing the staff's base near one's eye, an observer can measure the angle between two celestial objects. Dutch instrument-maker Johannes Van Keulen En Zoonen constructed this cross-staff in 1765.

A COPERNICAN ARMILLARY SPHERE replaced the central Earth with the Sun and also added planets. As general education progressed, wooden armillary spheres with glued-on paper scales replaced opulent metal ones. This French armillary sphere dates to 1846. Its maker is unidentified.

THE SEXTANT — encompassing one-sixth of a circle — was an expansion of the octant. Observers used it to measure larger celestial angles, up to 60°. Jesse Ramsden (1735–1800), the famous London instrument-maker, constructed this sextant around 1770.

EARLY SUNDIALS came in nearly two dozen varieties. This polyhedral sundial from the Adler Planetarium's collection reflects the skill of its unidentified maker, who lived in Europe around 1700. This sundial contains 12 pentagonal faces (counting the bottom).

generated by the planetarium's share of receipts from the Chicago World's Fair in 1933–34. The purchase increased the Adler's holdings to include many artifacts from Islamic societies and Asia.

The collection expanded under the guidance of curators Roderick and Marjorie Webster. Their special interest in astrolabes and sundials has made these areas of the collection particularly strong.

The Adler's Rare Book Collection contains more than 2,000 volumes, including more than a dozen incunabula (books printed before 1501). This collection includes the most important celestial atlases, many books on comets, early works on instruments, and astronomical and cosmological texts and tables.

Separate from the Rare Book Collection is the Adler's Works on Paper Collection. It contains about 550 individual maps, prints, and book plates featuring astronomical illustrations. Standouts in this collection include comet and eclipse broadsides, portrait prints, and celestial charts.

Adler also produces publications related to its instrument and book collections. *Western Astrolabes*, written by the Websters, appeared in 1998. Several other volumes are under way.

THE ECLIPSEOMETRIUM, a device used to predict upcoming eclipses, would have been a popular device for astrologers and astronomers alike in the 17th century. The maker of this device is unknown, but it was made in Venice around 1680.

AN ARMILLARY SPHERE takes its name from the Latin *armilla*, meaning bracelet. Earth occupies the center, and the outer band is the horizon. Gualterus Arsenius from Louvain, Belgium, made this armillary sphere in 1562.

THE ADLER'S OLDEST instrument is this astrolabe, made by Iranian Badr ibn `Abdallah in 1130. On its face, a rotating, cutaway disk called the rete represents the heavens as they revolve around us.

A NOCTURNAL follows the nightly movement of a few select stars. Usually, Polaris, the North Star, occupies the center position, and the nocturnal's movable arm points to the Big Dipper's Pointer Stars, which form the hour hand of a clock.

THIS GRAND ORRERY originally showed the planets out to Saturn when British instrument-maker Thomas Heath constructed it in 1740. Around 1797, the mechanism was expanded to incorporate the 1781 discovery of Uranus.

THIS POLYHEDRAL SUNDIAL constructed in Germany features an astonishing 29 gnomons (the part of a sundial that casts a shadow) on differently shaped surfaces placed at varying angles to the Sun's path across the sky. Unfortunately, both the maker and date are unknown.

Many visiting scholars also study the collection. "Their visits range from 1 hour to 5 weeks," Bolt said. "We also have university classes taking field trips here on a fairly regular basis."

A special place

As I walked through hallways marveling at Adler's history of astronomy exhibits, I asked Bolt if most of the collection was on display. "No," he replied. "Only about 10 percent is on public view at any time."

I asked him which object in the collection is his favorite. "I have two," he said. "One is the *Rudolphine Tables*, a combination of a star catalog and planetary tables written by Johannes Kepler. What makes our copy special is Kepler's signature."

The other is a leather-covered telescope made in Italy around 1630. "Although the maker is unknown, the little device is one of the world's six oldest telescopes. It's a real coup for us to have it here," Bolt explained.

The real accomplishment may be for the United States to have a collection like the one at Adler Planetarium. Because of Max Adler's foresight, generations of visitors have enjoyed — and will continue to experience — a visual history of astronomy through the tools astronomers used.

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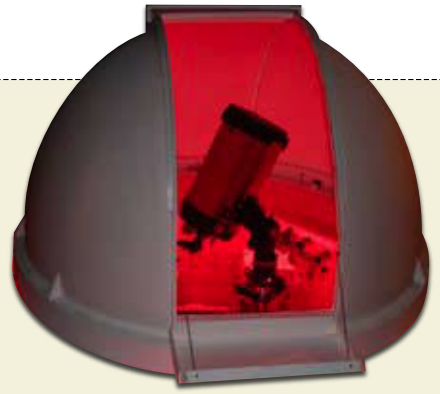

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STAR QUEST 2006 participants enjoyed activites ranging from observing to a swap meet. Star Quest 2007 is sponsored by the Central Appalachian Astronomy Club and the National Radio Observatory. ED CONNORS/GREEN BANK STAR QUEST

Speakers this year will include Harold A. McAlister, director for the Center for High Angular Resolution Astronomy, and West Virginia's Rocket Boys — amateur rocketeers who inspired the novel and movie *October Sky*.

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Eccles Ranch Observatory, Carlone, Alberta. 💻 www.calgary.rasc.ca/starbq2007.htm.

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Merritt Reservoir, near Valentine, Nebraska. 💻 www.nebraskastarparty.org.

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Victoria Fish and Game Protective Association, near Victoria, British Columbia. ✉ xasron@yahoo.ca; 💻 starfinders.ca.

JULY 20–22
Butterpot Star Party
Butterpot Provincial Park, near St. John's, Newfoundland. 💻 www.sji.ca/rasc.

JULY 21
Patoka Lake Star Party
Patoka Lake State Park, Birdseye, Indiana. 💻 www.louisville-astro.org.

CONTACT INFORMATION
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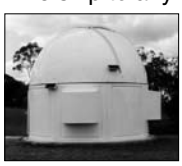

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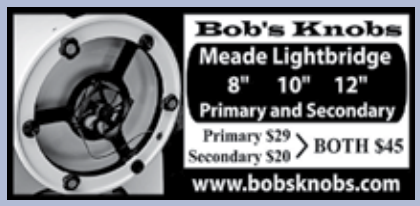

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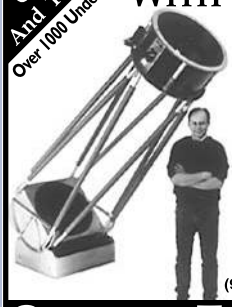

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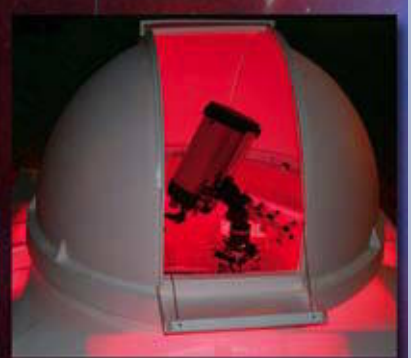

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Reader gallery

VELA SUPERNOVA REMNANT (8-inch ASA astrograph at f/3.8, FLI 6303E CCD camera, HαLRGB image with exposures of 40, 24, 20, 20, and 30 minutes, respectively) /// GERALD RHEMANN AND MICHAEL JÄGER, FARM TIVOLI, NAMIBIA

SUPERNOVA REMNANT

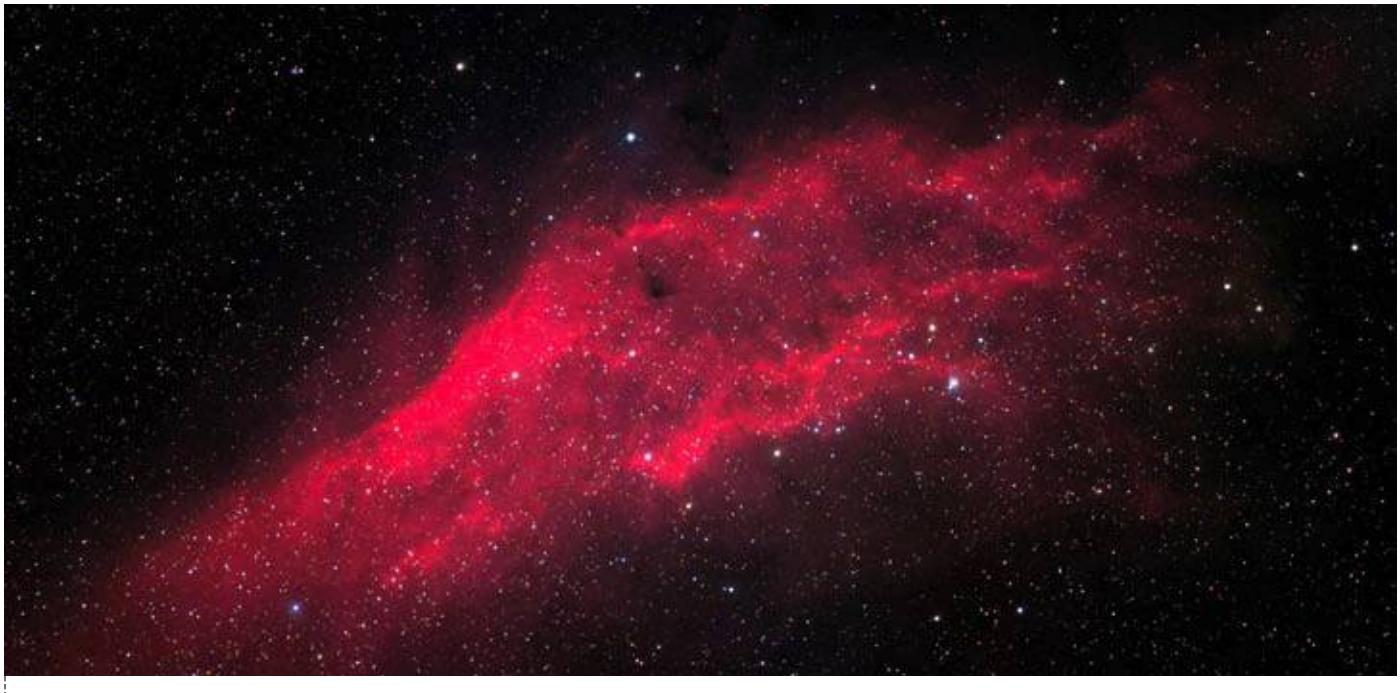
A blast from the past

The Vela supernova remnant resulted from the explosion of a massive star some 11,000 years ago in the Milky Way. Today, we see the expanding shell of gas as it interacts with material around it, called the interstellar medium. As atoms from the supernova's gas strike atoms of the interstellar medium, energy transfers between atoms, then gets reemitted as light of various colors. Nearby stars also help light up areas of gas. The Vela supernova remnant is part of a much larger complex called the Gum Nebula, which formed from an earlier supernova explosion. Both objects lie approximately 1,300 light-years away in the southern constellation Vela the Sails.

Send your images to: *ASTRONOMY* Reader gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of image and complete photo data: telescope, camera, and exposure information. To submit images electronically, visit www.contribute.kalmbach.com.

GLOBULAR CLUSTER M15 in Pegasus shines at magnitude 6.3 and measures 18' across. (20-inch RC Optical Systems Ritchey-Chrétien telescope, SBIG ST-10XME CCD camera, LRGB image with exposures of 22, 10, 10, and 15 minutes, respectively) /// **ADAM BLOCK/NOAO/AURA/NSF, KITT PEAK NATIONAL OBSERVATORY, ARIZONA**

BARRED SPIRAL GALAXY NGC 6744 in Pavo the Peacock sits in a rich star field and is inclined to our line of sight. (14.5-inch RC Optical Systems Ritchey-Chrétien telescope, SBIG STL-11000 CCD camera, LRGB image with exposures of 7.5, 3, 3, and 3 hours, respectively) /// **DANIEL VERSCHATSE, ANTILHUE OBSERVATORY, CHILE**



THE CALIFORNIA NEBULA (NGC 1499) in Perseus looks much better in photographs than it does to the eye because of its low surface brightness. A Hydrogen-beta filter increases the contrast. (4-inch Tele Vue TV-102is, 0.8x reducer, SBIG STL-11000M CCD camera, stack of seventeen 8-minute images taken through a Hydrogen-alpha filter) /// **JIM BURNELL, WARWICK, NEW YORK**

PLANETARY ALIGNMENTS can be tricky to capture if the weather is cloudy. The imager noted that it was difficult to get all four objects to peek out from behind clouds at the same time. (Canon Rebel digital SLR, 55mm lens at f/5.6, 1-second exposure, taken August 22, 2006, at 6:04 A.M. EDT) /// **GEORGE GAJDOS, AKRON, OHIO**

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement # 40010760.

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This remarkable image of the Helix Nebula was taken by Volker Wendel and Bernd Flach-Wilken with an SBIG STL-6303E camera through a 16" f/8 telescope. The final image combines 120 minutes of H-alpha data with 150 minutes of LRGB.

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